FM 6-120

AR DEPARTMENT FIELD MANUAL

FIELD ARTILLERY

BSERVATION BATTALION

RESTRICTED. DISSEMINATION OF RESTRICTED MATTER. No person is entitled solely by virtue of his grade or position to knowledge or possession of classified matter. Such matter is entrusted only to those individuals whose official duties require such knowledge or possession. (See also paragraph 23b, AR 380–5, 15 March 1944.)

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RESTRICTED

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This manual supersedes FM 6-120, 29 June 1939, including C1, 10 December 1943, and Tentative Appendix, 1 July 1944.

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United States Government Printing Office
Washington : 1945

WAR DEPARTMENT
WASHINGTON 25, D. C., 1 May 1945

FM 6–120, Field Artillery Observation Battalion, is published for the information and guidance of all concerned.

[AG 300.7 (1 Apr 45)]

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Refer to FM 21–6 for explanation of distribution formula.

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CHAPTER 1

GENERAL PRINCIPLES AND ORGANIZATION

Section I. GENERAL

1. PURPOSE AND SCOPE. a. This manual furnishes a guide for the training and employment of field artillery observation battalions. For tactics and technique common to all field artillery battalions, not contained in this manual, see FM 6–101.

b. The methods set forth herein are flexible and the principles embodied are basic; the various methods presented may be employed under the conditions best suited for their use.

2. MISSIONS. a. The missions of the observation battalion are—

(1) Location of enemy artillery.
(2) Registration and adjustment of friendly artillery fire.
(3) Collection of information.
(4) Coordination of survey.
(5) Comparative calibration of friendly artillery.
(6) Providing meteorological data to friendly artillery.

b. Missions (1) through (5) are treated individually in this manual. Determination of meteorological data is covered in TM 20–240.

Note. For military terms not defined in this manual see TM 20–205 and for index to references see FM 21–6.

Section II. ORGANIZATION AND EQUIPMENT

3. GENERAL. The operations discussed in this manual are not limited by a specific Table of Organization and Equipment. All methods described herein are applicable with any Table of Organization and Equipment similar to those in effect at the date of this publication. See current T/O & E 6–75, 6–76, and 6–77, for personnel allotted to each component of the battalion.

4. EQUIPMENT. So far as permitted by the special nature of much of the equipment, methods discussed in this manual are not limited to specific models of items of equipment. See current Tables of Organization and Equipment and the appropriate Technical Manuals for information on particular items of equipment. The methods described herein are applicable to any item of required equipment the basic design of which is similar to those in use at the date of this publication.

5. OBSERVATION BATTALION. a. One observation battalion is assigned to each corps and with headquarters and headquarters battery, corps artillery, it is the only organic part of the corps artillery.

b. The observation battalion is motorized and consists of a headquarters and headquarters battery and two observation batteries. The battalion staff is organized as follows:

Individual	*Principal duties*
Battalion commander	Commands battalion; corps artillery survey officer.
Executive	Second in command; S–1; commands the rear echelon.
S–3	Operations and training.
Assistant S–3 (S–2)	Operations and training.

Individual	*Principal duties*
Battery commander, headquarters battery	Communication officer; commands headquarters battery.
S-4	Supply and motor officer.
Personnel officer (WO)	Assistant adjutant.
Supply officer (WO)	Assistant supply officer.
Survey officer*	Survey officer.

6. HEADQUARTERS AND HEADQUARTERS BATTERY (fig. 1). Headquarters and headquarters battery consists of a battalion headquarters, battery headquarters, operations platoon, topographic platoon, communication platoon, service platoon, personnel section, and maintenance section. The operations platoon contains the operations section and the meteorological section. Functions peculiar to the headquarters battery of an observation battalion are as follows:

a. Meteorological (metro) section obtains meteorological data for artillery, sound ranging, and, when requested, for the air forces.

b. Topographic platoon performs the field work necessary to the coordination of surveys performed by artillery with the corps and by the observation battalion.

c. Service platoon has the normal supply and motor maintenance functions of the separate battalion.

d. Operations section in addition to establishing the battalion command post, establishes a survey information center for the collection and dissemination of survey information and the coordination of surveys performed by artillery with the corps and by this observation battalion.

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* When available a coast and geodetic survey officer may replace one officer of the battalion.

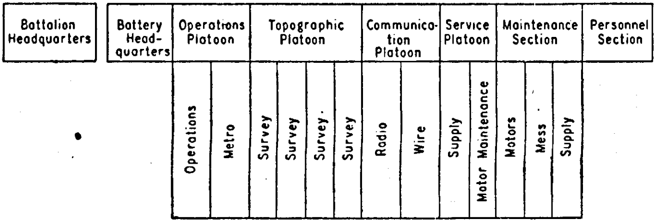


Figure 1. Battalion headquarters and headquarters battery.

7. OBSERVATION BATTERY (fig. 2). Each observation battery contains a battery headquarters, a flash ranging platoon, a sound ranging platoon, a communication platoon, and a maintenance section.

a. Battery headquarters normally contains the clerks, messengers, and command post personnel of the battery.

b. Flash ranging platoon contains the personnel necessary for flash ranging. It is commanded by a first lieutenant, who is the flash ranging officer of the battery. He has an assistant, a second lieutenant, who is the survey officer for the flash ranging platoon. The flash ranging platoon is subdivided as follows:

(1) *Operation section* performs the necessary drafting, plotting, and computation for the platoon; installs and operates the flash ranging central; and normally furnishes the observers and recorders for four observation posts.

(2) *Topographic section* consists of two survey parties which perform the necessary survey operations for the platoon.

c. Sound ranging platoon contains the personnel necessary for sound ranging. It is commanded by a first lieutenant who is the sound ranging officer of the battery. He has an assistant, a second lieutenant, who is the survey officer

for the sound ranging platoon. The platoon is subdivided as follows:

(1) *Operation section.* The plotting group performs the necessary drafting, plotting, and computation for the platoon; installs and operates the sound ranging central; and furnishes the sound outpost observers.

(2) *Topographic section* consists of two survey parties which perform the necessary survey operations for the platoon.

d. Communication platoon is responsible for the installation and maintenance of the battery wire and radio systems of the sound and flash platoons, and for the installation, operation, and maintenance of the wire and radio nets.

e. Maintenance section furnishes the personnel for the battery mess and supply and for the maintenance of motor transportation.

Headquarters	Flash Ranging Platoon				Sound Ranging Platoon				Communication Platoon		Maintenance Section		
	Operation		Topographic		Operation		Topographic						
	Plotting and Central	Observing	Survey	Survey	Plotting and Central	Observing	Survey	Survey	Radio	Wire	Motors	Mess	Supply

Figure 2. Observation battery.

CHAPTER 2

TACTICAL EMPLOYMENT

Section I. EMPLOYMENT

8. GENERAL. The field artillery observation battalion is employed to assist the artillery with the corps by locating hostile installations (*particularly hostile artillery by its sound and flash*), registering and adjusting fire of friendly artillery, providing survey control, collecting combat intelligence, and furnishing metro and comparative calibration data for artillery. Technical considerations involved in the effective accomplishment of these functions should be left to the observation battalion or battery commander who should keep higher headquarters advised as to capabilities and limitations under existing conditions.

9. PRINCIPLES OF EMPLOYMENT. The observation battalion is normally employed under centralized control. When the observation battalion commander cannot exercise centralized control, the attachment of batteries to divisions or task forces may be made. The attached observation battery is employed as a unit to provide the division with combat intelligence (particularly the location of hostile artillery) and to adjust artillery fire. Survey is provided to assist the division in establishing survey control. Any employment of observation units should exploit their inherent capabilities of coordinated long-range observation. The capability of prolonged operation should not be compromised by installations so far forward as to be subjected to frequent interruptions from enemy action or hostile mortar fire.

Section II. CENTRALIZED CONTROL

10. GENERAL. The observation battalion is employed as a unit. Counterbattery intelligence from the observation battalion is transmitted directly to the corps artillery counterbattery intelligence officer; other combat intelligence is transmitted to the corps artillery fire-direction center in accordance with established procedure. Common survey control is provided for the corps and division artillery. Complete wire communication systems are established and all installations are accurately located by survey.

11. ORGANIZATION FOR COMBAT. A typical organization of the observation battalion under centralized control is shown in figure 3. The organization of a position consists of all the operations necessary to prepare the unit for the effective accomplishment of its mission. The battalion command post is located where it can most efficiently control its batteries and is accessible to the corps artillery fire-direction center. Normally, the battalion command post is located near the corps artillery fire-direction center.

12. INSTALLATIONS. Normally complete reconnaissance, survey, and communication should precede the occupation of position. However, the battalion is capable of going into position rapidly. (See par. 15 and chs. 4 and 6.) The completed installation shown in figure 3 may be the result of a progressive development following an initial hasty occupation of position. On a wide front both observation batteries may be deployed abreast; or the sector width may be such that one battery in position is sufficient. A salient may require not only the normal installations of both observation batteries but additional installations, using the spare or emergency equipment of battalion, in which case the capacity of the battalion to operate for extended periods of

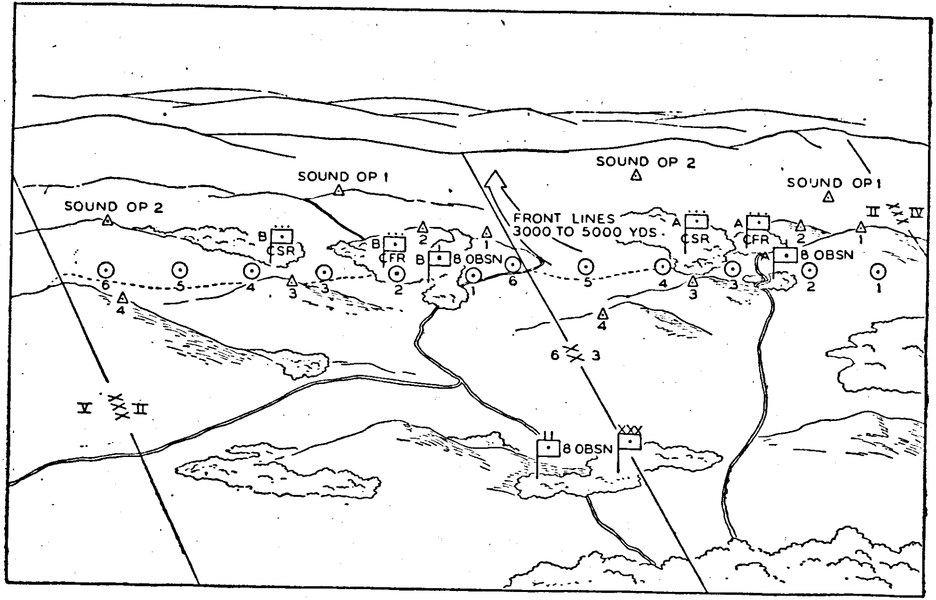


Figure 3. Observation battalion in position, centralized control.

time is substantially reduced. Both sound and flash installations should be deployed in such a manner as to cover the suspected mass of hostile artillery. Separate zones of observation for flash and sound should be avoided wherever possible. The mission, terrain, enemy activity, and disposition of our own troops will determine the type of installation that will be used.

13. DISPLACEMENT. Displacement is usually made by battery in the assigned zone of action (usually the zone of action of the corps) and in such a manner that observation is continuous. Adequate prior planning and continuous reconnaissance are essential so that displacement can be made either forward or to the rear in the shortest possible time.

Section III. DECENTRALIZED CONTROL

14. EMPLOYMENT. The observation battery is fully equipped to sustain itself in action and can execute all of the missions of the observation battalion except for determining and furnishing metro data. It should be employed as a unit. The observation battery is employed as the counterbattery intelligence agency for the division in much the same manner as the observation battalion is employed by corps. To facilitate early entry into action, reconnaissance elements of the observation battery should be well forward in the leading march columns of the division. (See fig. 4.)

15. ORGANIZATION. The initial installations of sound and flash units may be rapid installations with a minimum of survey and wire communication. Progressive development of position commences immediately and continues until a displacement is necessary. The completed organization of the battery position is shown in figure 5.

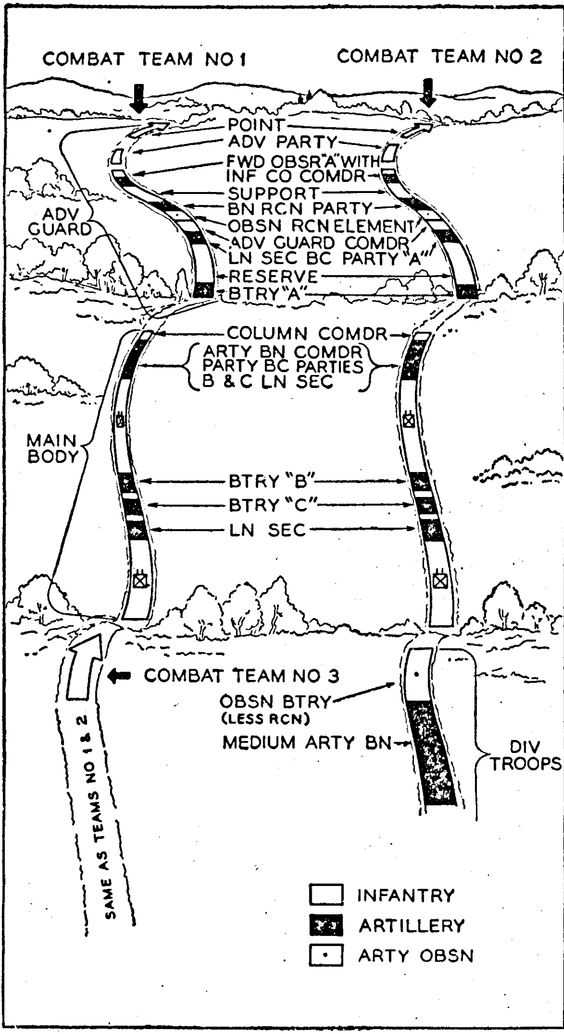


Figure 4. Observation battery marching with the division.

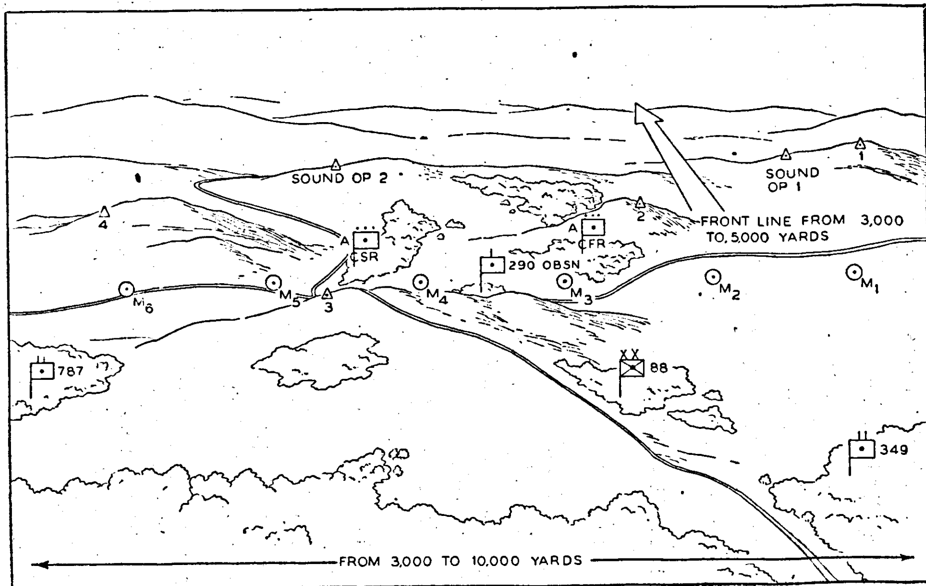


Figure 5. Observation battery in position.

16. DEVELOPMENT OF POSITION. Installations are progressively developed by any of the following:

a. Improving the sound and flash base survey.

b. Connecting the base surveys with fire-direction survey.

c. Establishing common survey control.

d. Establishing communication appropriate to the organization for combat.

e. Expansion to long bases.

f. Relocation or reorientation, if necessary.

17. INSTALLATIONS. a. To facilitate flash and sound installations, the following information should be furnished, or should be obtained by, the flash and sound officers:

(1) Situation.
(2) Zone of observation.
(3) Base points, check points, and other critical points.
(4) Priorities for observation.
(5) Firing chart (map, photograph, grid, observed).
(6) Survey and registration.
(7) Location of battalion command post (fire-direction center).
(8) Position area of firing batteries.
(9) Restrictions on areas for bases.
(10) Communication.

b. The type, location, and the method of installation depend upon the mission, terrain, time available and the tactical situation; no general rules can be given. For a full discussion of types and methods of installation of sound and flash ranging systems, see chapters 5 and 6.

18. DISPLACEMENT. Displacement is usually made by elements of the sound and flash platoons in such a manner as to make observation continuous. Reconnaissance and plan-

ning are carried on continuously. Survey and communication should be established in the new position area prior to displacement from the old.

Section IV. SURVEY

19. GENERAL. The survey sections of the observation batteries are primarily concerned with survey of sound and flash ranging installations. In decentralized situations they also assist with the establishment of control for the division artillery. The extension of survey control is a continuous process and is carried on by all available survey personnel. Headquarters battery topographic platoon performs the field work necessary to the coordination of all of the artillery survey in the corps. (See ch. 4.)

20. SURVEY OFFICER. The observation battalion commander is the corps artillery survey officer. Under the direction of the corps artillery commander, the survey officer—

a. Plans the corps artillery survey.

b. Coordinates the survey of the observation battalion with other artillery units with the corps.

c. Maintains liaison with the topographic engineer unit operating with the corps, and obtains control data available to and provided by the engineer unit.

d. Establishes a survey information center for gathering and disseminating survey information.

21. ORIGIN OF CONTROL. The origin of the common grid for corps artillery survey is either arbitrary or true control.

a. Arbitrary control is survey based on assumed coordinates for the starting point and an assumed direction. It should approximate true control in direction and altitude to facilitate use with metro data.

b. True control is control that has been tied into the adopted survey system (military grid) being used. These data are procured from topographic engineers, existing maps, or lists of existing control.

22. SURVEY PLAN. The survey plan, in nearly all instances, has for ultimate goal the establishment of a common grid system for the entire corps. Except where common control is already available, each artillery survey unit initiates survey with an arbitrary origin. The observation battalion survey ties the arbitrary surveys together on the adopted common grid. Where true control is available, the observation battalion connects the corps survey to true control and makes the necessary conversion to place the entire corps on true control. The plans for, execution of, and final dissemination of corps artillery survey information is the responsibility of the corps artillery survey officer.

23. SURVEY INFORMATION CENTER. A survey information center is established to serve as an agency for the planning, collection, evaluation, and dissemination of survey data. Normally, the survey information center is part of the battalion command post. Its location and time of opening should be announced in the corps artillery orders. During the initial phases of an operation, the survey information center is generally well forward not only to coordinate more efficiently the survey work in progress, but to be more accessible to artillery units to which survey data is being provided.

Section V. INTELLIGENCE

24. GENERAL. The observation battalion is essentially the counterbattery intelligence agency of the corps. The measure of success of the battalion is not only in its ability to obtain

accurate information, but also in the speed with which this information is transmitted to higher headquarters in order that it may be acted upon. All locations, all azimuths and estimated ranges, and all intelligence must be reported without delay no matter how inaccurate or unnimportant they seem. The rule is: *first early information and then accurate information.*

25. KINDS OF INFORMATION. By flash ranging and sound ranging, the observation battalion furnishes information on the locations of enemy artillery and the effect of friendly artillery fire. Flash-ranging observers particularly have the additional mission of general battlefield surveillance by visual observation; they can report locations of front lines, friendly and enemy troop movements, location and character of enemy installations, etc. All personnel in the observation battalion are impressed with the importance of early information and are trained to seek it by all means available.

26. TRANSMISSION OF INFORMATION. The observation battalion carefully evaluates all information received from its subordinate units. During centralized operation, this information is transmitted to the corps artillery fire-direction center with the least possible delay. In decentralized operations, information is furnished directly to the supported unit.

Locations of enemy troops and installations are normally sent in the clear; friendly locations are sent in code.

Section VI. METEOROLOGICAL SECTION

27. GENERAL. The meteorological section of the observation battalion furnishes metro data for the artillery with the corps, and for sound ranging, on call or on schedule. Metro data may also be furnished to the Army Air Forces and

antiaircraft artillery upon request. Any type metro message required for artillery use can be furnished. Metro messages, encoded in proper form, may be transmitted by telephone, telegraph, radio, or messenger. In order to make use of existing communication facilities, the metro section normally operates in the vicinity of the battalion command post. Liaison is normally established with Army Air Forces weather sections in the vicinity not only to provide the metro section with data, but to obtain forecasts in the absence of other metro data. See TM 20–240 for technical information concerning the preparation of metro messages.

Section VII. CONDUCT OF FIRE

28. GENERAL. If conditions are favorable, adjustment, registration, and transfers of fire may be conducted by sound and flash ranging. Adjustment and registration follow standard gunnery procedures described in chapters 5 and 6 of this manual and FM 6–40.

Section VIII. ORDERS

29. GENERAL. a. The field artillery subparagraph of a corps field order will contain only those instructions to the observation battalion which are necessary to provide for its coordinated employment. Frequently, only brief instructions pertinent to organization for combat, survey, and observation will be included. Where employment of the observation battalion requires no special instructions, written orders are usually omitted from corps orders and verbal instructions are the rule. The observation battalion commander advises the corps artillery commander concerning the employment of the observation battalion. See FM 6–100 for details of the corps artillery plans and orders.

b. The observation battalion commander's orders to his batteries are usually oral, and may be fragmentary or complete. Full use should be made of warning orders.

30. CHECK LIST FOR BATTALION ORDER.

1. *a. Enemy situation:*

    General disposition.

    Artillery, known or suspected.

    b. Own troops:

    Plan of supported unit.

    Artillery, disposition and general plan of employment.

2. Mission of this battalion, including priority and zones of observation.

3. *a. Battery A:*

    Zone of observation (sound and flash); priorities.

    Flash observation posts, limitations, locations of observation posts.

    Sound base, type and location.

    Special instructions:

    Survey.

    Communication.

    Counterbattery plan.

    Registrations (sound and flash).

    b. Battery B. (Same as battery A.)

    x. (1) *Survey:*

    Control.

    Firing chart.

    Plan, organization and assignment of survey parties.

    Survey information center; location and time of opening.

(2) *Metro message:*

Schedule for artillery and sound ranging messages.

Special instructions concerning preparation of metro messages and communication of metro messages.

(3) *Local and individual security:*

Local protection, antiaircraft, antitank, ground and paratroop.

Obstacles and mines.

Warning systems.

(4) *Instructions regarding movement:*

Route.

Destination.

Speed.

Special instructions for march security, route marking, order or march, initial point, release point, and other details appropriate to the situation.

4. *Administrative matters* (reference will be made usually to a separate administrative order). Instructions to batteries concerning all classes of—

Supplies and supply points.

Location of battalion aid stations.

Salvage.

Captured matériel and prisoners of war.

Traffic restrictions, route marking.

Traffic priorities.

Restricted areas.

Mail.

Shelter.

Reports.

Other miscellaneous matters.

5. *Communication:*

Wire.

Radio.

Codes.

Location of command posts.

31. CHECK LISTS FOR BATTERY ORDERS.

1. *Movement orders:*

Present location.

Route.

Destination.

Speed.

Special instructions for marching security, route marking, order of march, initial point, release points, and other details appropriate to the situation.

2. *Orders for occupation of position:*

Situation, enemy and own troops.

Mission, to include attachment or support status.

Observation:

Zone.

Priorities.

Base and check points.

Locations of installations.

Location of survey information center.

Survey:

Plan and organization.

Firing chart.

Registration.

Local security:

Antiaircraft, antitank, ground, and paratroop defense.

Obstacles and mines.

Location of machine guns.

Location of sentinels.

Warning system.

Location of truck park.

Special instructions relative to conduct of fire:

Positions of firing battery and battalion fire-direction center; counterbattery plan; other details appropriate to the situation.

Administrative details (see par. 30):

Location of kitchens, schedules, and method of feeding.

Location of supply points.

Location of battalion aid station (covered in battalion field order).

Communication (covered in battalion field order).

Notes. 1. Upon concluding an oral order, synchronize time and ask for questions.

2. Orders must be given to fit a situation and not a check list. Many points listed here may be covered in the standard operating procedure of the unit.

3. Orders must be clear, concise, and timely.

4. For other details, see FM 101-5.

CHAPTER 3

COMMUNICATION

Section I. GENERAL

32. GENERAL. This chapter covers only such information on signal communication as relates specifically to the observation battalion. For general principles and procedures for field artillery signal communication, see FM 6–101. Communication training must include all means of communication and must be given to all personnel. A commander must provide adequate communication with all elements of his command and with supported and adjacent units. *No one means of communication can be considered infallible; alternate means of communication must be tested and must be immediately available.*

33. COMMAND POST. a. General. The command post is the center of all agencies of communication. Operation of all elements of a command post is continuous. Officers provide for continuous operation as necessary and enlisted personnel work in shifts. When an additional echelon of a command post is established, elements are divided to permit operation at both echelons.

b. Elements. Elements of a battalion command post are—

(1) *Switching central.* The focal point of wire communication is the switching central. It is located 75 to 100 yards from the battalion command post and message center, on the side of the command post area from which the majority of wire circuits will be laid.

(2) *Message center.* The message center is located near the battalion command post, on the principal route of incoming traffic.

(3) *Battalion command post.* The battalion command post consists of the operations section, communication personnel, and equipment necessary to enable the battalion commander to supervise the battalion in the accomplishment of its mission. It is located where maximum safety and security are available and where interference and interruptions may be avoided.

(4) *Radio and panel station.* The radio and panel station consists of the radio set operating in the higher head quarters command net, any other relatively high-powered radio sets, panel display ground, and a pick-up station. It is located 300 to 500 yards from other elements, preferably on a flank. It is connected by remote control to the battalion command post.

Section II. WIRE

34. GENERAL. a. The primary means of signal communication in an observation battalion is wire. However, radios are provided for initial communication installations and for emergency use.

b. Wire is the usual means of transmission of sound signals from the sound ranging microphones to the sound recording equipment. See paragraph 37 for radio sound data transmission system.

35. WIRE NETS. a. Normal wire circuits and systems in the observation battalion are shown in figure 6. These circuits are installed by the observation battalion communication personnel unless orders to the contrary are issued. Variations from, and additions to, the wire circuits and systems

indicated must be considered, and appropriate orders issued. The organization away from which the arrow points usually installs that circuit in order to expedite the installation of the wire system. In a decentralized operation the supported unit installs a wire line to the observation battery.

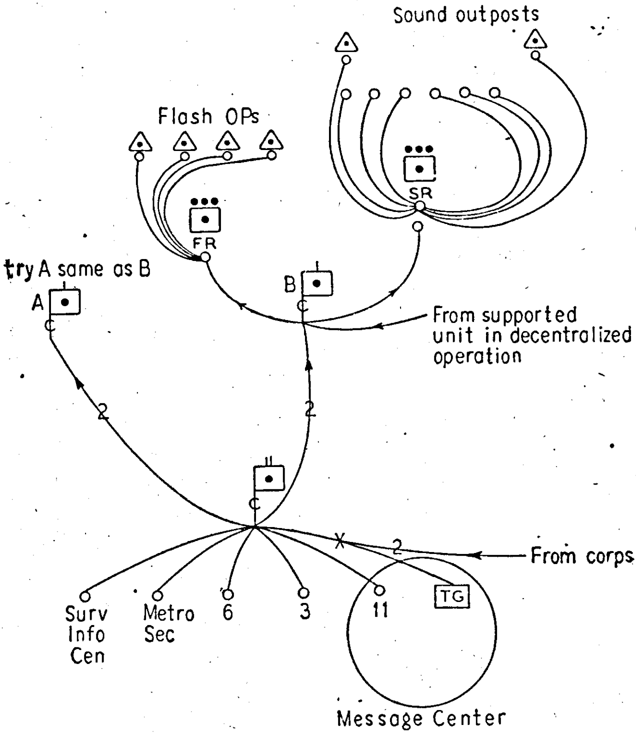


Figure 6. Wire net, observation battalion.

b. Procedures outlined in FM 24–20 are followed in the installation of observation battalion wire circuits.

Section III. RADIO

36. RADIO NETS. a. Radio channels are allotted to the observation battalion by corps. A minimum of four channels should be available. Figure 7 indicates a normal battalion radio net. All elements of this net are installed by the observation battalion.

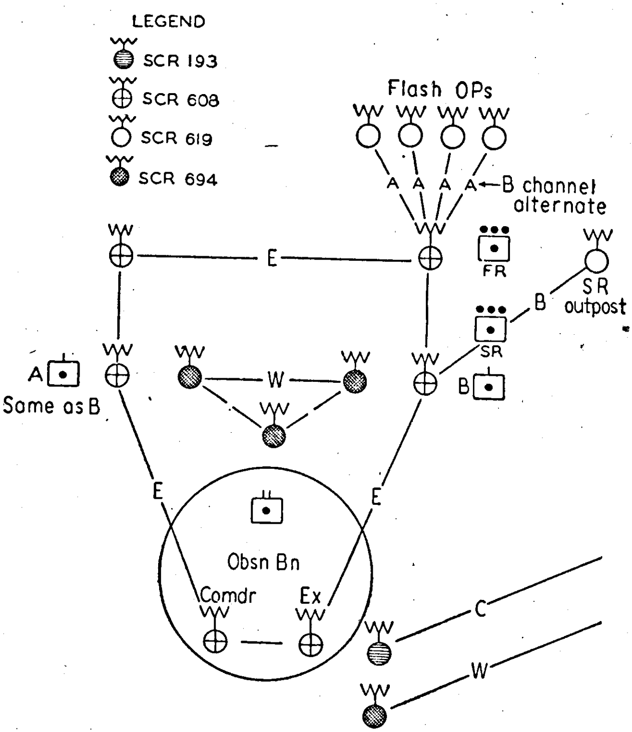


Figure 7. Normal battalion radio net.

b. Each observation battery is assigned a minimum of two channels, *A* and *B*. *A* channel is used for the flash rang-

ing net. *B* channel is used for communication between the sound outpost and the sound ranging central. Each channel is an alternate for the other in case of jamming; but operation on an alternate channel must be restricted to emergencies. *A* or *B* channel may be used as an alternate for *E* channel in case of jamming.

c. *E* channel is used for the battalion control net. *W* channel is used for the battalion command net which operates before installation and during interruption of wire communication. At least one alternate *W* channel should be provided if sufficient channels are available.

d. Additional radio sets, if available in the battalion, may be used to provide for special needs of survey personnel. When radio communication beyond the range of field artillery radio sets is necessary, higher headquarters should be requested to furnish the radio sets and operators.

37. RADIO SOUND DATA TRANSMISSION SYSTEM. The sound ranging platoon may operate with radio communication between outposts, microphones, and sound ranging central. For this purpose additional radios are required, one at each outpost and microphone position and a corresponding number of radios at the sound ranging central. A separate channel is required for each microphone. See appropriate Technical Manuals for details regarding operation and maintenance instructions.

CHAPTER 4

SURVEY

Section I. GENERAL

38. GENERAL. This chapter contains a general description of the survey operations of the observation battalion, with particular emphasis on (1) types of survey, (2) required accuracies, (3) survey missions, and (4) surveying equipment used. (For general theory and technical discussion of surveying, see any standard surveying text, FM 6–40, TM 5–235, TM 44–225.)

a. Missions. The survey mission of the observation battalion includes the coordination of survey of all artillery with the corps. The establishment of all corps artillery on common control, the collection and dissemination of all survey information within the corps artillery, and the survey of flash and sound ranging installations are all the responsibility of the observation battalion.

b. Organization. The observation battalion commander is the corps artillery survey officer. With the assistance of his battalion survey officer, the observation battalion commander plans, executes the survey, and establishes a survey information center for the dissemination of survey data. The observation battalion is provided equipment for 12 survey parties: 4 in headquarters battery and 4 in each observation battery. There are two parties in each sound ranging platoon and each flash ranging platoon, and normally these survey parties execute survey to establish the sound and flash ranging installations. However, the battalion survey officer is

free to pool his survey parties in any manner that will best accomplish the survey mission.

c. Survey planning. The first consideration in making a survey plan is the existence of survey control and suitable maps. The corps topographic engineers are responsible for the extension of control to areas readily accessible to the observation battalion. (See FM 5–6.) However, when control is not available, the observation battalion adopts an arbitrary grid system and proceeds with survey without delay. Normally, in such cases each sound and flash installation assumes its own starting data for the origin of its survey work. Headquarters battery survey platoon may also assume an arbitrary datum and may tie in artillery position areas, the target area, and sound and flash installations to this datum. Eventually, when common control is available, all control is converted to the common grid. The type of firing chart to be used will depend on the maps available and survey conditions existing and will change, as shown above, as the survey plan progresses. (See FM 6–40.)

d. Execution of survey. The observation battalion executes the highest order of survey (1/3000 to 1/5000 accuracy) performed within the field artillery. Accuracy required depends on the particular mission assigned. The required accuracy must never be sacrificed in the interest of speed, although speed is an everpresent requirement. In addition to providing control for its own installations, the battalion provides place marks for the corps and division artillery. The location, elevation, and an azimuth for each of these place marks is furnished by the survey information center. This agency is established as a part of the battalion command post; here surveys are planned, field data collected and processed, and files kept of all available survey control. The survey information center should be kept advised of all survey needs and all survey data should be obtained from this center.

39. TRANSIT AND ACCESSORIES. a. Use. The transit is used for measuring horizontal and vertical angles, for prolonging straight lines with accuracy, for leveling, and for measuring distances by stadia. Transits are used by field artillery observation battalions for the measurement of angles in surveying. Transits issued to observation battalions are graduated in degrees, with a least reading of 20 seconds. (See fig. 8.)

Figure 8. The transit.

b. Verniers. All transits are equipped with verniers. A vernier is an auxiliary scale used for reading fractions of the

smallest division of the main scale. The use of a vernier is based on the fact that it is easier to determine coincidence of two lines than to estimate fractions of a scale interval. Instructions for reading verniers are contained in TM 5–235.

c. Accessories. Each transit is equipped with a reading glass for verniers, with a plumb bob, sunshade, screw driver, adjusting pins, and waterproof cover. The plumb bob is used for centering the transit accurately over the station mark; the sunshade, to replace the cap on the objective lens during work; the screw driver and adjusting pins, to adjust the transit. Some transits are equipped with a prismatic eyepiece with dark glass slide for attachment to the regular eyepiece in observing objects of high altitude, the dark glass being employed whenever the sun is observed.

d. Setting up transit. Instructions for setting up the transit are given in TM 5–235.

40. MEASURING HORIZONTAL ANGLES WITH TRANSIT.

a. With the instrument set up over the station at which the angle is to be read, set the zero of the *A* vernier opposite the zero of the horizontal circle, using the upper clamp and tangent screw to bring them into coincidence. Read the *B* vernier for a check. Using the lower motion, point approximately at the first object by looking over the top of the telescope. Move the telescope until the vertical cross hair is very nearly on the point, clamp the lower plate by means of the lower clamp thumb screw, and set exactly on the point by the lower clamp tangent screw. The line of sight is now on the first object. To measure the angle, loosen the upper clamp, turn the telescope to the second point, set approximately on the point, clamp the upper plate, and set the vertical cross hair exactly on the point by the upper tangent screw. The degrees and minutes of the angle

are then read, using the *A* vernier which was set at zero. Now read the *B* vernier. The mean of the two vernier readings gives the seconds of angle. Never overrun the point in bringing the vertical cross hair upon it. Bring the cross hair to the point in such a manner that the tangent screw compresses the spring against which it works. This eliminates lost motion in the plates.

b. A complete measurement of any angle should consist of the mean of two readings, one with the telescope *direct* and one with the telescope *reversed.* The angle is first measured as described in a above; the telescope is plunged and, using the *lower motion only,* the first object is sighted upon; using the upper motion, the telescope is set exactly on the second object; the angle now on the transit is twice the value of the angle measured. This method eliminates most of the instrument errors.

c. Angles by repetition. The mean of a number of measurements of an angle gives a value of the angle more nearly accurate than any single measurement. As a minimum, one direct and one reversed reading should always be made; a maximum of six direct and six reversed readings will usually give the maximum desired accuracy. In any case, the same number of direct and reversed readings should be made. The direct readings are first made cumulatively; the telescope is plunged and, after sighting back on the first object with the lower motion, the operator makes reversed readings cumulatively. If, for example, there were three direct and three reversed readings, the value of the angle read on the vernier is 6 times that of the desired angle. (Add the multiples of 360° to this reading and divide by 6 to obtain the desired angle.)

41. MEASURING VERTICAL ANGLES WITH TRANSIT.

Level the horizontal plate accurately, sight on the point with the telescope direct, and read the vertical angle. Plunge the

telescope, rotate the instrument in azimuth 180°, sight upon the point, and read the vertical angle again. The mean of the two readings is taken.

42. RUNNING OR PROLONGING A STRAIGHT LINE WITH TRANSIT. a. To run a straight line between two points which are intervisible, set up over one point, *A,* and sight on the other point, *B.* This procedure establishes the line, and any number of intermediate points may be set in this line of sight.

b. If the two points between which a straight line is desired are not intervisible, set up as nearly as possible on the line between them and at such a point that both are visible from the instrument. Sight on one point, plunge the telescope, note how much this trial line varies from the second point, and estimate the next position for the transit. A point on the line is finally found by successive approximations. This is a slow process; to acquire aptitude requires considerable practice on the part of the operator.

c. To prolong a line from two points, the method in a above can be used if the prolongation of the line is visible from *A.* If the prolongation of the line is not visible from *A* (fig. 9), set up over *B,* sight on *A,* and plunge the telescope. The vertical cross hair will now prolong the straight line if the instrument is in adjustment, and points *C* and *D* may be set in on the continuation of the line. If the transit is not in adjustment, set out the points *C′* and *D′* on the new line, rotate the plate 180°, sight again on *A,* and plunge as before, setting new points *C″* and *D″* on the continuation of the line. Equidistant between the point *C′* and *C″*, and *D′* and *D″* will be found the true points, *C* and *D,* of the straight line.

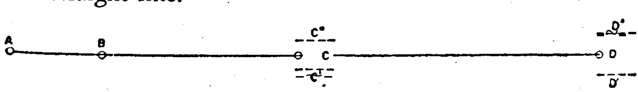


Figure 9. Running or prolonging a straight line.

43. RANGE POLES. Range poles are usually 8 or 10 feet long, round or hexagonal, and about 1 inch in diameter. They are made of wood shod with an iron point or of steel rod or tubing; and are usually painted alternately red and white in bands of equal width. The range pole is used to mark a point on the ground so as to make it visible from a distance. The sharp point of the pole may be placed on a tack head in a stake. The rod is plumbed by balancing it between the fingertips of both hands, the rodman standing squarely behind it, facing the instrument. It also may be used for lining up or ranging in lines, in which case, the rodman carries the pole vertically, moving right, left, backward, or forward as directed by signal from the instrument man.

44. STADIA. a. Stadia is a method for measuring distances by reading an intercept on a graduated rod; it is used when extreme precision is not required. For this purpose, two additional horizontal hairs, called stadia hairs, are carried in the transit telescope on the same reticle as the cross hairs and are placed equidistant from the horizontal hair.

b. In the observation battalion, stadia may be profitably used for checking taped distances. See TM 5–235 for complete instructions in the use of the stadia.

45. METHODS OF SURVEY. a. All survey performed by the observation battalion is precise survey, requiring precise instruments and solution by computation. Graphic methods may be used for rough checks and approximations only.

b. The greatest precision consistent with the time available should be sought. The hurried use of precise methods may cause mistakes and great inaccuracies. In survey work and in training for it, the following should be observed:

(1) Use the most precise method the available time permits.

(2) Even though time is pressing, never use a method that is not capable of producing satisfactory data.

(3) Check all work if only by a rough method. Employ completely independent checks by different men.

(4) Watch particularly the preparation of notes; these must be legible, accurate, and clear. More mistakes occur through badly kept notes than through errors in measurements or calculations.

(5) Develop methods and procedure that produce accuracy and eliminate mistakes. Enforce these methods rigidly.

(6) Study methods to avoid the *weak link*. One inaccurate step will destroy the accuracy of an otherwise precise survey.

(7) Use selected men. Remove men who do not become precise and methodical with reasonable training. A good survey man rarely makes a mistake.

c. Basic survey operations in the observation battalion consist of the location of points, the measurement of distances and angles, and the determination and transmission of direction. Points are located horizontally by traverse, resection, and triangulation. They may be located by inspection approximately if a map or photomap shows the desired point or a feature very close to it. Distances and directions are determined by traverse or by triangulation. Direction is determined from two known points or by astronomical methods. Direction is transmitted by measuring or computing angles. The altitudes of points are determined by computations using distances and vertical angles, by leveling, or by altimeter.

46. SURVEY ACCURACY (see FM 6–40). **a. Survey accuracy of 1/3000.** (1) *Purpose.* Traverse or triangulation over long distances, location of flash and sound installations and short bases.

(2) *Primary instruments required.* A 20-second transit, 100-foot steel tape, and accessories.

(3) *Procedure.* Tape read to the nearest 0.01 foot. Horizontal taping, leveling the tape within 1½ feet and a 20-pound estimated pull. Slope taping with difference of elevation of tape ends determined by leveling or slope angle to the nearest ¼ foot, and slope corrections applied.

Transit angles to 10 seconds or better, at least one direct reading and one reversed, or preferably two direct and two reversed with 20-second transit.

b. Survey accuracy of 1/5000. (1) *Purpose.* Very long traverses or triangulation schemes, and short bases where the angle of intersection is very small.

(2) *Instruments required.* A 20-second transit, 100-foot steel tape, and accessories.

(3) *Procedure.* Tape estimated to 0.001 foot and slope corrections applied for differences of elevation of tape ends of 0.1 foot. Standard pull on tape with spring balances. Use great care in alignment. Make temperature corrections for temperatures which are more than 20° F. above or below standard for tape (usually 68° F.).

Transit angles to 5 seconds or better. With 20-second transit, three (four) direct and three (four) reversed readings and, if time permits, six direct and six reversed.

Section II. TRAVERSE

47. GENERAL. a. Definitions. (1) A *traverse* is a series of contiguous course lines whose lengths and relative directions have been determined. Stations on the traverse are located with respect to one another.

(2) A *closed traverse* is a traverse which ends at the starting point or at another point of known location.

(3) An *open traverse* is a traverse which does not end at a known point.

(4) A *station* is a marked point, usually where the course or direction changes.

(5) A *leg* is a straight line between two adjacent stations.

b. Procedure. (1) Distances are determined by taping between adjacent stations.

(2) Angles measured are the clockwise angles from the last station occupied to the next forward station to be occupied.

(3) In running a traverse, altitudes may be determined by measuring the vertical angles between stations.

(4) The closing of a traverse is a valuable check against blunders and should always be performed if possible. It also permits the traverse to be adjusted, if necessary.

(5) The locations of stations are usually marked by setting a short stake flush with the ground surface and driving a tack at the exact point. A witness stake is set about 1 foot from the station, slanted toward it, and labeled with station number, party that established it, and other data.

48. PERSONNEL AND DUTIES OF A TRAVERSE PARTY.

a. A traverse party of an observation battalion consists of the following personnel:

1 Transitman
2 Computers
2 Rodmen
2 Tapemen
—
7 Total

b. The transitman may serve as chief of party and recorder. If available, a separate chief of party should be provided.

c. The computers compute the traverse as the survey progresses, computing independently as a mutual check.

d. When required, axemen supplement the party.

e. The rodmen hold the rods on the foresight (front rodman) and backsight (rear rodman).

f. (1) Tapemen perform their duties as described in TM 5-235.

(2) Tapemen should be carefully trained in proper procedure. Prescribed methods should be rigidly enforced. Tapemen must exercise constant vigilance to avoid errors and blunders. The most common blunders are reading the tape incorrectly and losing a complete tape length.

(3) *Don'ts* for tapemen:

(*a*) Don't jerk the tape.

(*b*) Don't pull the tape when it is kinked.

(*c*) Don't let vehicles run over the tape.

(*d*) Don't bend the tape sharply around corners.

(*e*) Don't split hairs in lining in.

(*f*) Don't allow the chaining pin to be disturbed.

(*g*) Don't pull the pin until you are sure that it will not be needed again.

(*h*) Don't break tape oftener than necessary. Each break slows up the work and introduces another chance for error.

(*i*) Don't fail to wipe the tape clean and dry before putting it away.

(*j*) Don't forget that methodical procedure prevents errors and makes speed.

49. TRAVERSE COMPUTATIONS. a. General. Computations in the observation battalion are precise. Seven-place logarithms are habitually used to reduce interpolation and to obtain the accuracy desired.

b. Types. Traverse computations consist of determination of coordinates from azimuth measured and distance taped. For this operation, a standard form (FAS Form 2) has been provided to facilitate field computations. Initial azimuth may frequently be determined from the known coordinates of two intervisible points. For this operation, a standard form (FAS Form 1) has also been provided.

c. Example (fig. 10). The coordinates of stations *A* and *K* are known. Station *K* is visible from station *A*. The azimuth *A* to *K* is computed on FAS Form 1. (See fig. 11.) Station *A* is occupied and the clockwise angle from *K* to *B* turned. Coordinates of station *B* are computed on FAS Form 2. Successively, stations *B* and *C* are occupied and the angles from the respective preceding stations to the respective succeeding stations turned. Coordinates of each successive station are computed on FAS Form 2, as the survey progresses. (See fig. 12.)

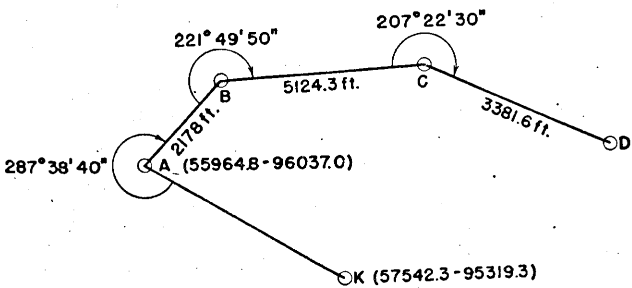


Figure 10. Short traverse.

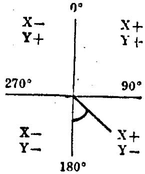
AZIMUTH AND DISTANCE FROM COORDINATES

Stations		X		Y	
From	A	(−)	55964.8	(−)	96037.0
To	K	(+)	57542.3	(+)	95319.3
		ΔX	1577.5	ΔY	717.7

$$\text{Tan } \alpha = \frac{\Delta X}{\Delta Y} \qquad D = \frac{\Delta X}{\text{Sin } \alpha} = \frac{\Delta Y}{\text{Cos } \alpha}$$

Log ΔX	3.1979694		
−Log ΔY	2.8559429		
Log Tan α	0.3420265	α	65° 32′ 11″
Cos			179° 59′ 60″
Log ΔX*	3.1979694	Azimuth	114° 27′ 49″
−Log Sin α*	9.9591485		
Log D	3.2388209	D	1733.09 yards

SKETCH

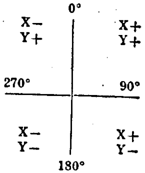


Stations		X		Y	
From		(−)		(−)	
To		(+)		(+)	
		ΔX		ΔY	

$$\text{Tan } \alpha = \frac{\Delta X}{\Delta Y} \qquad D = \frac{\Delta X}{\text{Sin } \alpha} = \frac{\Delta Y}{\text{Cos } \alpha}$$

Log ΔX			
−Log ΔY			
Log Tan α		α	
Log ΔX*		Azimuth	
−Log Sin α*			
Log D		D	yards

SKETCH



*Note: If ΔX is less than ½ΔY, enter Log ΔY instead of Log ΔX and Log Cos α instead of Log Sin α in these spaces.

FAS Form No. 1

FAS, Fort Sill, Okla., (6-5-44—127,000)—29414

Figure 11. Azimuth and distance from coordinates. (Sample computation.)

COORDINATES FROM AZIMUTH AND DISTANCE

Traverse from Station A to Station D — Sheet 1 of 1 Sheets

Station	Azimuth	°	′	″	Direction to Next Station	Distance to Next Station	Logarithms		Coordinates and X and Y Differences	
Sta. K	Az. to Next Sta.						NOTE: To find ΔX and ΔY in meters, use log of distance in feet, and add 9.484 0158.			
Sta. A	±	180	00	00	Y				X 55964.80	Y 96037.00
	Az. to Last Sta.	114	27	49	X− Y+ / X+ Y+					
	Angle Turned	287	38	40		3) 2178 ft.				
						D = 726 yd.	D 2.8609366	D 2.8609366		
	Sum	402	06	29	X− Y− / X+ Y−		Sin α 9.8264188	Cos α 9.8703356		
	−	(360	00	00)						
	Az. to Next Sta.	42	06	29	α = 42° 06′ 29″		ΔX 2.6873554	ΔY 2.7312722	ΔX +486.81	ΔY +538.61
Sta. B	±	180	00	00	Y				X 56451.61	Y 96575.61
	Az. to Last Sta.	222	06	29	X− Y+ / X+ Y+					
	Angle Turned	221	49	50		3) 5124.3 ft.				
						D = 1708.1 yd.	D 3.2325133	D 3.2325133		
	Sum	443	56	19	X− Y− / X+ Y−		Sin α 9.9975674	Cos α 9.0234012		
	−	(360	00	00)						
	Az. to Next Sta.	83	56	19	α = 83° 56′ 19″		ΔX 3.2300817	ΔY 2.2559145	ΔX +1698.56	ΔY +180.27
Sta. C	±	180	00	00	Y				X 58150.17	Y 96755.88
	Az. to Last Sta.	263	56	19	X− Y+ / X+ Y+					
	Angle Turned	207	22	30		3) 3381.6 ft.				
						D = 1127.2 yd.	D 3.0520010	D 3.0520010		
	Sum	471	18	49	X− Y− / X+ Y−		Sin α 9.9692317	Cos α 9.5604716		
	−	(360	00	00)						
	Az. to Next Sta.	111	18	49	α = 68° 41′ 11″		ΔX 3.0212327	ΔY 2.6124726	ΔX +1050.10	ΔY −409.71
Sta. D	±	180	00	00	Y				X 59200.27	Y 96346.17
	Az. to Last Sta.				X− Y+ / X+ Y+					
	Angle Turned					3) .... ft.				
						D = ... yd.	D	D		
	Sum				X− Y− / X+ Y−		Sin α	Cos α		
	−	(360	00	00)						
	Az. to Next Sta.				α =		ΔX	ΔY	ΔX	ΔY ....
Sta.	Computer				Checker		Date		X	Y ....

F.A.S. Form No. 3 — F.A.S. Fort Sill, Okla. (6-19-46—385,000)—29830 577-370 A

Figure 12. Coordinates from azimuth and distance. (Sample computation.)

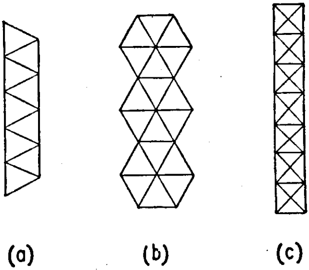
50. GENERAL. a. Generally, survey control is most rapidly expanded throughout a large sector by a scheme of triangulation. In densely wooded country, without points of vantage, triangulation may be rendered impossible but where triangulation is possible, it is usually rapid and accurate, if carefully done.

b. The lines of a triangulation scheme form a network, tying together the stations at which the angles in the scheme are measured. The vertices of the triangles are the triangulation stations. (See fig. 13.)

51. TRIANGULATION SCHEMES. a. The basic figure of a triangulation scheme is the triangle. The triangle alone affords no check on the observations and computations other than requiring the three interior angles of the triangle to total 180°. A triangulation scheme consisting of a single chain of triangles, though rapid, is usually weak due to lack of sufficient checks. The figures in a strong triangulation scheme are so arranged that there is a minimum of two independent chains of triangles through which the computations for any point may be carried. Whenever the triangulation scheme must extend through several triangles, or under any other conditions when time permits, the triangulation scheme should consist of a system of multiple chains of triangles overlapping frequently. This provides a check on the observations and computations.

b. Simple figures providing adequate checks for use in a triangulation scheme are the quadrilateral with both diagonals observed, the three-sided central point figure, and the four (or more) sided central point figure. These figures are normally arranged in the scheme to form chains of quadrilaterals or other figures, to provide a check on the

work. Figure 13 illustrates three types of triangulation schemes.



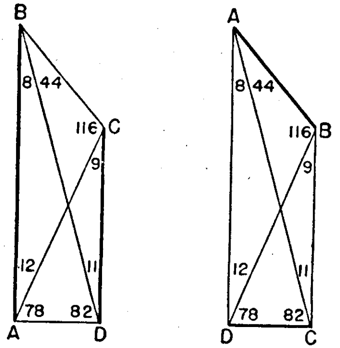
(a) Single chain of triangles
(b) Multiple chain of triangles
(c) System of quadrilaterals

Figure 13. Triangulation schemes.

52. ACCURACY. a. Accuracies obtained are dependent to a large degree upon the *strength of figure* of the triangles involved in a triangulation scheme. An equilateral triangle is the strongest possible triangle and a right-angle quardilateral is the strongest possible quadrilateral. All angles through which computations are carried should be between 30° and 150°, in order to obtain the accuracy required in the control survey performed by an observation battalion. (See fig. 14.)

b. Control survey performed by an observation battalion requires that distances, and the sides of triangles, should check with an accuracy of between 1 in 3,000 and 1 in 5,000. Triangles should have an average closure of 12 seconds or better. Angles should be measured with an accuracy of 4 seconds or better, making three direct and three reversed readings with a 20-second transit.

c. If the angles through which computations are carried are not between 30° and 150°, the accuracy of the angular measurements must be increased to achieve results of the required accuracy.



(a) Strong Quad

(b) Weak Quad

In both figures AB is the known side and CD the side sought.

In strong quad (a) all angles used in computations are between 30° and 150°.

$$\frac{AB}{\text{Sin } 116} = \frac{AC}{\text{Sin } 52}$$

$$\frac{AC}{\text{Sin } 93} = \frac{CD}{\text{Sin } 78}$$

In weak quad (b) all angles used in computations are not between 30° and 150°.

$$\frac{AB}{\text{Sin } 12} = \frac{BD}{\text{Sin } 52} = \frac{AD}{\text{Sin } 116}$$

or

$$\frac{AB}{\text{Sin } 11} = \frac{AC}{\text{Sin } 125} = \frac{BC}{\text{Sin } 44}$$

$$\frac{BD}{\text{Sin } 93} = \frac{BC}{\text{Sin } 78} = \frac{CD}{\text{Sin } 9}$$

or

$$\frac{AC}{\text{Sin } 90} = \frac{AD}{\text{Sin } 82} = \frac{CD}{\text{Sin } 8}$$

Figure 14. Strong and weak figures.

53. TRIANGULATION PROCEDURE. Execution of a triangulation scheme consists of the following steps:

a. Reconnaissance for triangulation stations. Selection of the most suitable triangulation stations in the scheme

must be made by thorough reconnaissance both on the map and on the ground.

b. Marking stations. Each station to be occupied must be marked with a stake or by other means, to fix its exact position. Each station to be observed must be marked by some device visible from all stations from which it is to be observed. A bipod or similar marker which will permit the station to be occupied without disturbing the marker will frequently be necessary.

c. Measurement of angles. All angles at each station, including the angle closing the horizon, are measured. These angles are adjusted for error of closure of the horizon. Error of closure of the horizon is distributed equally among the angles measured, irrespective of the size of the various angles.

d. Measurement of a base line when necessary. A base line will be required if in the scheme there are not two or more control stations, the positions of which are fixed by higher survey control. When the measurement of a base line is necessary, it must be measured with an accuracy of 1 in 5,000 or better.

e. Computations. (1) Computations include the adjustment of the observed angles, the computation of the length of each side of each triangle, and the coordinates of each station.

(2) The unit for computing is the triangle. The observed angles, adjusted for horizon closure, are entered in the triangle. The three interior angles of the triangle are then adjusted to total exactly 180°, the error of closure in the triangle being divided equally among the three angles of the triangle. All computations are made using the adjusted angles. Each triangle is adjusted independently of every other triangle, beginning with the observed angles in each case.

(3) Usually the quadrilaterals and figures, other than triangles, will not close perfectly. To cause all figures to close perfectly requires a least square or similar adjustment, which is not justified in triangulation of the order of accuracy normally required of an observation battalion.

54. RESECTION. a. Resection is a specialized form of triangulation employed to locate individual points which are visible from other known points. The accuracies specified above for triangulation are applicable to resection operations. Normally, in observation battalion survey, the three-point resection is the most frequently used and is always solved mathematically.

b. In a three-point resection, the coordinates of three points visible from the position of the observer must be known in order to determine the coordinates of the position of the observer.

(1) In figure 15, *A*, *B*, and *C*, are the known points and

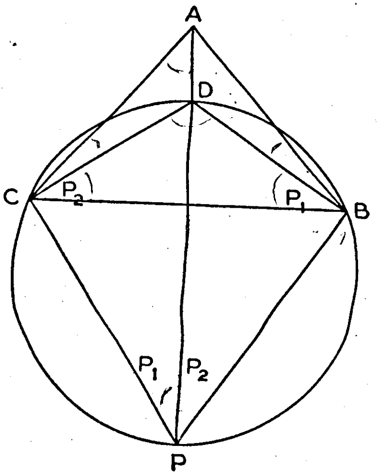


Figure 15. Three-point resection.

P the position of the observer, from which the angles CPA and APB and BPC (to close the horizon) are measured. These angles are adjusted for horizon closure.

(2) From the coordinates of A, B, and C, solve for the azimuth and length of the lines AB, AC, and BC. From these azimuths, compute the angles ACB, CBA, and BAC, and solve for the coordinates of P by the following steps:

Note. Angle DBC = angle DPC ($= P_1$) since both are angles whose vertices lie on the circumference of a circle and subtend the same arc on the circle.

Angle DCB = angle DPB ($= P_2$) for the same reason.

Computations:

	Solution	*Check solution*
1st Step:	Solve triangle DBC for DC.	Solve triangle DBC for DB.
	$DC = \dfrac{BC \sin P_1}{\sin BDC}$	$DB = \dfrac{BC \sin P_2}{\sin BDC}$
2d Step:	Solve triangle ADC for angle DAC.	Solve triangle ABD for angle BAD.
	$\tan DAC = \dfrac{DC \sin ACD}{AC - (DC \cos ACD)}$	$\tan BAD = \dfrac{DB \sin DBA}{AB - (DB \cos DBA)}$
3d Step:	Solve triangle PCA for PA and PC.	Solve triangle PAB for PA and PB.
	$PA = \dfrac{AC \sin ACP}{\sin P_1}$	$PA = \dfrac{AB \sin PBA}{\sin P_2}$
	$PC = \dfrac{AC \sin PAC}{\sin P_1}$	$PB = \dfrac{AB \sin BAP}{\sin P_2}$
	Compute the coordinates of P from point C or A.	Compute the coordinates of P from point B or A.

Checks: 2d step, angle BAC = angle DAC + angle BAD.

3d step, length of PA should check from solution and check solution.

Coordinates of P should check when computed from PC, PA, or PB.

c. Two-point resection (inaccessible base) is discussed in TM 5–235.

d. Semi-graphic resection (multiple points) is discussed in TM 5–235.

Section IV. VERTICAL CONTROL

55. GENERAL. a. Purpose. Elevations of points are determined primarily for the use of the artillery in computing firing data. In order to accomplish this, the observation battalion normally carries elevation above sea level or an assumed elevation to the field artillery battalion place mark and to the flash observation posts. This vertical control is then extended into the target area by means of trigonometric leveling. The angle of site to targets and high bursts is observed and this data transmitted to the fire-direction center. Under ordinary conditions, the elevations of the sound installation are not required.

b. Accuracy. An elevation accurate to the nearest 5 to 10 feet is sufficient for most artillery purposes. The artillery officer needs to know the difference in elevation between the gun and the target. When a good contour map is available, spot elevations may be picked off the map with sufficient accuracy. When such maps are not available, the elevations must be determined by survey. It is most desirable to have all corps artillery on a common vertical control datum, either true or assumed, as soon as possible, and this is always accomplished if time permits.

56. METHODS. a. Leveling. Differential leveling may be performed with the transit. Self-reading rods or stadia should be used and readings made only to 0.1 foot. The algebraic difference of the sum of foresights (—) and the sum of the back sights (+) gives the difference in elevation desired. (See TM 5–235.)

b. Trigonometric leveling. The angle of site may be measured with either the transit or one of the flash observing instruments. The distance is obtained by any survey method or is scaled from a map and the difference of elevation obtained by solving the vertical triangle. (See TM 5–235.) For the best results, simultaneous reciprocal observations should be made, which cancels out the effect of curvature and refraction. If the vertical angle is measured in only one direction, a correction must be applied for curvature and refraction for a more accurate determination of the elevation. This correction may be neglected for points in the target area at distances less than 5,000 yards. (See sec. IX, ch. 9 for curvature and refraction corrections.)

c. Surveying altimeter (fig. 16). The altimeter is essentially an aneroid barometer which measures atmospheric pressure. Since atmospheric pressure and elevation above sea level are closely related, the altimeter is used to determine the difference of elevation between two points not over 6 to 8 miles apart. Two instruments are in use at present: one measures elevation to 6,000 feet in 10-foot divisions; the other measures elevations to 15,000 feet in 20-foot divisions. For a complete description and discussion of the use and care of these instruments see TM 5–9418 and TM 5–9420. Figure 17 shows a sample record and computations for leveling with altimeters.

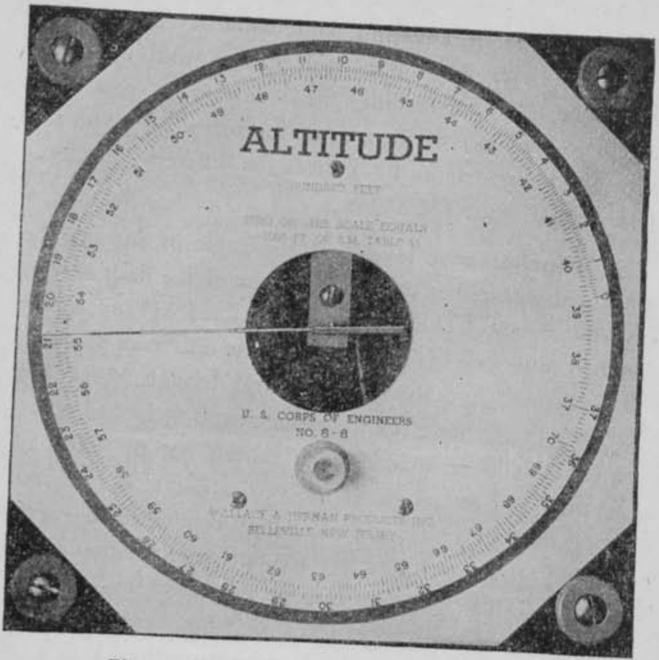


Figure 16. Altimeter, surveying, 6,000 feet.

Section V. ASTRONOMIC OBSERVATIONS

57. GENERAL. a. Purpose. Astronomic observations made by the observation battalion are primarily for the purpose of (1) obtaining a starting azimuth when no line of direction is available or when no established, intervisible points exist, (2) checking the azimuth of a traverse leg as brought forward through a succession of turning points, (3) establishing a declination station for field artillery use, or (4) establishing the azimuth of an orienting line for field artillery use. Observation may be made using the sun, moon, or any of the common stars.

EXAMPLE OF COMPUTATION

LEVELING WITH ALTIMETERS—FIELD OBSERVATIONS AND COMPUTATIONS

Instrument No. 6-44 Date 10 Feb. 44 Observer R. S. Smith Recorder R. S. Smith

Weather Clear Cool State Oklahoma County Comanche

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Station	Field Time	Obs. Field Alt.	Field Temp.	Mean Temp.	Index Diff. + −	Field Indexed (3+6)	Obser. Sta. Alt.	Indic. Diff. (7−8) + −	Temp. Corr. + −	Diff. Corr. (9+10) + −	Unadj. Elev.	Clos. Adj. + −	Adj. Elev.	Known Elev.
BM 850	0530	2100	35	35	+20	2120	2120	0	0	0	—	—	—	850 Ft
Sta. A	0640	3606	32	34	+20	3626	2124	+1502	−48	+1454	2304	−2	2302	—
Sta. B	0740	2172	49	50	+20	2192	2130	+62	± 0	+62	912	−3	909	—
Sta. C	0930	2304	54	55	+20	2324	2132	+192	+2	+194	1044	−6	1038	—
Sta. D	1040	2180	63	64	+20	2200	2140	+60	+2	+62	912	−8	904	—
BM 850	1100	2133	65	65	+20	2153	2145	+8	—	+8	858	−8	850	850

Computed by R. S. Smith Checked by C. J. Jones Date 10 Feb. 44

REMARKS:

Figure 17. Sample computation, leveling with altimeters.

b. Methods. Two standard methods are used: (1) the altitude method and (2) the hour angle method. The hour angle method generally produces the best results; however, correct time is essential and the computations are slightly more difficult. The altitude method requires that the heavenly body be in a certain position at time of observation. It should be between 20° to 60° in altitude and 2 hours from the observer's meridian. Depending on existing conditions, therefore, the method which can best obtain the desired results should be used.

58. PROCEDURE. a. Identification. To obtain an astronomic azimuth, it is necessary to identify the heavenly body on which the observations are made. This can be done by the use of star charts or the use of a star finder which is entered with certain observed data after the observing is completed. There are a number of star charts which can be used. The Rude Star Finder, which is available through the United States Navy Hydrographic Office, is an excellent mechanical device for identifying the stars.

b. Observing (fig. 18). (1) *Altitude method.* The field work consists essentially of measuring the altitude of the heavenly body, the horizontal angle from the celestial body to a terrestrial mark, and the time of each pointing on the sun or star. The observer's latitude and longitude and watch correction must be known. The latitude and longitude can be taken from a map and time need be known only to the nearest minute to obtain an azimuth correct to 10 to 20 seconds.

(2) *Hour angle method.* Field work consists of measuring the horizontal angle from the celestial body to a terrestrial mark and the time of each pointing on the heavenly body. The latitude, longitude, and watch correction must be known (and for purpose of identification of the stars, the approximate bearing and altitude should be noted). Lati-

tude and longitude may be taken from a map with sufficient accuracy but correct time must be known to 5 or 10 seconds in order to obtain an azimuth correct to 10 to 20 seconds. (See TM 5–235 for detailed discussion on observing procedure.)

c. Computation. Two standard forms, FAS Form 10 and 11, have been provided on which the azimuth computations for any observation can be made. The American Ephemeris and Nautical Almanac for the current year and a table of logarithms are needed for the computation. The solution of the spherical triangle (pole, zenith, star), shown in figure 18, is possible when any three of the six elements, one of which must be a side, are known. Parallax and refraction tables are found in TM 5–236.

d. Examples. Computation of an observation on the sun and two observations on the stars are shown in figures 19, 20, and 21. These observations have been made by both the hour angle and altitude methods.

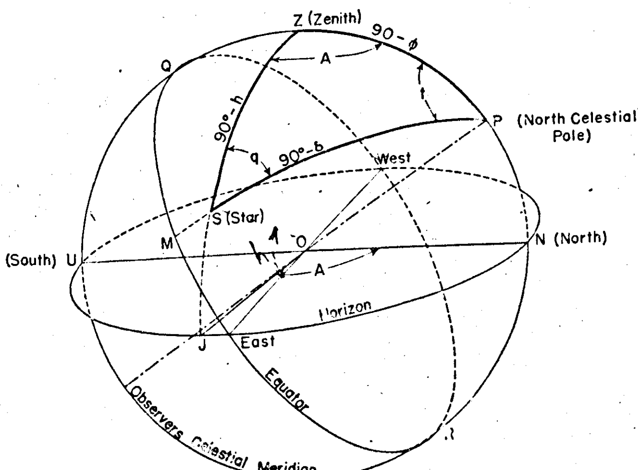


Figure 18. Celestial sphere, showing the "pole, zenith, star" triangle.

AZIMUTH BY SUN ~~OR A STAR~~, ALTITUDE METHOD

Set up at STA. NO. 10
Celestial Body SUN
Mark BEACON LIGHT
Date 5-6-44
Latitude Φ 34° 39' 34"
Longitude 98° 24' 18"
Time Zone Central War Time 75th Meridian
Watch F(−) or ~~S(+)~~ 60 Seconds
Watch Checked Against RADIO
Locality GUNNERY HILL Ft. Sill Okla
Weather CLEAR, WARM, CALM
Temperature 56° F
Instrument No. 401411
Greenwich Date 5-6-44

Tel.	Object	Time hr	Time min	Time sec	Horizontal Angle °	Horizontal Angle '	Horizontal Angle "	Vertical Angle °	Vertical Angle '	Vertical Angle "
D	Mark	—	—	—	0	00	00	—	—	—
D	☉ (Apparent Sun Position)	10	14	26	313	47	20	43	01	—
D	☉	—	16	07	314	05	20	—	21	—
D	☉	—	17	06	314	15	00	—	32	—
R	☉	—	19	04	315	17	40	—	25	—
R	☉	—	20	31	315	34	20	—	43	—
R	☉	—	21	37	315	45	40	—	56	—
R	Mark	—	—	—	0	00	40	—	—	—
Mean		10	18	08	314	47	43	43	29	40
Watch Corr		(−)	1	00	Parallax + (sun only)					06
Time Zone Corr		5	00	00	Refraction −				01	00
GCT		15	17	08	Altitude h			43	28	46

	°	'	"
Declination δ at 0ʰ GCT ±+	16	26	18.3
GCT × δ Variation per hr ±		10	42.3
Corrected Declination δ ±	16	37	00.6

Observer M. Sgt. H. R. BECK
Recorder S. Sgt. R. J. HOOVER

	°	'	"
p	73	22	59
Φ	34	39	34
h	43	28	46
Sum 2)	151	31	19
s	75	45	40
s−p	2	22	41
s−Φ	41	06	06
s−h	32	16	54

$p = 90° - \delta$ $\quad s = \frac{1}{2}(p + \Phi + h)$

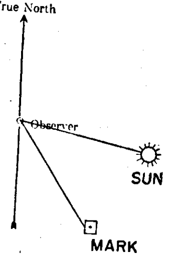
A = Azimuth of S East or West of True North

$$\tan \tfrac{1}{2} A = \sqrt{\frac{\sin(s-\Phi)\sin(s-h)}{\cos s \cos(s-p)}}$$

Colog Cos	0.6091261
Colog Cos	0.0003742
Log Sin	9.8178278
Log Sin	9.7276078
Sum 2)	20.1549359
Log Tan ½ A	0.0774680

	°	'	"
½ A	50	05	00
A (E ~~or W~~ of North)	100	10	00
Azimuth to SUN	100	10	00
Minus Angle, Mark to SUN	314	47	43
True Azimuth to Mark	145	22	17
Grid Correction		47	56
Grid Azimuth to Mark Zone "D"	146	10	13

Sketch



Computed by M. A. H. Date of Computation 5-6-44

FA* Form No. 11

FAS, Fort Sill, Okla., (8-16-44—24000)—20424

Figure 19. Azimuth of sun, altitude method.

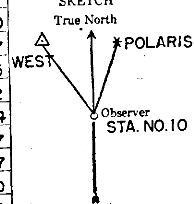
AZIMUTH BY A STAR, HOUR-ANGLE METHOD

Set up at... STATION NO. 10
Star S... POLARIS
Mark... STATION WEST
Date... 5 JULY 1943
Latitude Φ... 34° 39' 34"
Longitude... 98° 24' 18"
Time Zone 75th MERIDIAN (CWT)
Watch F(−) or ~~S(+)~~ ... 12 ... Seconds
Watch Checked Against... RADIO
Locality... FORT SILL
Weather... CLEAR, WARM
Observer... JONES
Recorder... SMITH
Instrument No... 14783
Greenwich Date... 6 JULY 1943

Tel.	Rep.	Time hr	Time min	Time sec	Horizontal Angle °	Horizontal Angle '	"Verniers A	"Verniers B	"Verniers Mn.
D	0	—	—	—	0	00	00	20	10
D	1	22	09	20	10	22	20	—	—
D	2	22	11	51	—	—	—	—	—
D	3	22	14	24	31	09	00	—	—
R	4	22	16	49	—	—	—	—	—
R	5	22	19	34	—	—	—	—	—
R	6	22	21	56	62	22	20	00	10
			93	54	62	22	—	—	00
Mean		22	15	39	10	23	—	—	40
Watch Corr			−	12					
Time Zone Corr		5	00	00					
(1) GCT		3	15	27					

	hr	min	sec
(2) Greenwich Sidereal Time at 0ʰ GCT (Ephemeris)	18	52	25
(3) Correction, Mean Solar Time to Sidereal Time of Observation (Table III, Ephemeris)		4	32
(4) Greenwich Sidereal Time of Observation (1) + (2) + (3)	22	08	24
(5) Longitude $\boxed{W(-)}$ E(+) (in hr, min, sec)	6	33	37
(6) Local Sidereal Time (4) + (5)	15	34	47
(7) Right Ascension of Star (Ephemeris)	1	44	40
(8) Local Hour Angle of Star (6) − (7)	13	50	07

SKETCH



Declination δ of Star (Ephemeris) = 88° 59' 21"

t = Equivalent of (8) in deg, min, sec = 207° 31' 45"   Φ = 34° 39' 34"

Log Tan δ... 1.753 3982   Log Cos t... 9.947 8138(n)   Log Sin t... 9.664 8300
Log Cos Φ... 9.915 1606   Log Sin Φ... 9.754 8813   Log (a−b)... 1.673 2329
Sum = Log a... 1.668 5588   Sum = Log b... 9.702 6951   Diff. = Log Tan A... 7.991 5971
a... 46.619   b... − 0.504   A... 0°33'43"
b... (−) 0.504
a − b... 47.123

$$\text{Tan A} = -\frac{\text{Sin t}}{\text{Cos}\,\Phi\,\text{Tan}\,\delta - \text{Sin}\,\Phi\,\text{Cos t}} = -\frac{\text{Sin t}}{a-b}$$

A = Azimuth of Star S East (A+) or West (A−) of True North.

	°	'	"
Azimuth to Star	0	33	43
Minus Angle, Mark to Star	10	23	40
True Azimuth to Mark	350	10	03
Grid Correction		47	56
Grid Azimuth to Mark	350	57	59

INSTRUCTIONS

See TM 5-235 Paragraph 178c.

Check Signs and Quadrants by use of Sketch.

Computed by A. J. H.   Date of Computation 7-5-43

FAS, Fort Sill, Okla., 7-6-44—4,000)—29639   375-A

FAS Form No. 10

Figure 20. Azimuth of star, hour angle method.

AZIMUTH BY ~~SUN OR~~ A STAR, ALTITUDE METHOD

Set up at.. STATION NO. 12A
Celestial Body Star β Pegasi
Mark.. △ WEST
Date.. SEPT. 11, 1944
Latitude Φ. 34° 39' 34"
Longitude... 98° 24' 18"
Time Zone... 75 MER. W.
Watch F(−) or ✓S(+).. +13 ..Seconds
Watch Checked Against.. RADIO
Locality... FORT SILL
Weather... CLEAR ... COOL
Temperature... ————
Instrument No. 20" Tr. No. 17642
Greenwich Date. SEPT. 12, 1944

Tel.	Object	Time hr	Time min	Time sec	Horizontal Angle °	Horizontal Angle '	Horizontal Angle "	Vertical Angle °	Vertical Angle '	Vertical Angle "
D	Mark	—	—	—	0	00	00	—	—	—
D	+	20	56	01	98	10	20	35	57	—
D	+	20	57	32	98	20	40	36	17	—
D	+	20	59	06	98	31	00	36	38	—
R	+	21	01	14	98	45	00	37	05	—
R	+	21	02	48	98	55	20	37	27	—
R	+	21	04	19	99	05	40	37	48	—
R	Mark	—	—	—	0	00	40	—	—	—
	Mean	21	00	10	98	38	10	36	52	00
	Watch Corr		+	13	Parallax + (sun only)				—	
	Time Zone Corr	5	00	00						
					Refraction −				01	17
	GCT	2	00	23	Altitude h			36	50	43

Apparent Sun Position

	°	'	"
Declination δ at 0h GCT ±			
GCT × δ Variation per hr ±			
Corrected Declination δ ±	+ 27	46	59

Observer..... A. J. H.
Recorder.... M. M. H.

	°	'	"
p	62	13	01
Φ	34	39	34
h	36	50	43
Sum 2)	133	43	18
s	66	51	39
s−p	4	38	38
s−Φ	32	12	05
s−h	30	00	56

$p = 90° - \delta$ $s = \frac{1}{2}(p + \Phi + h)$

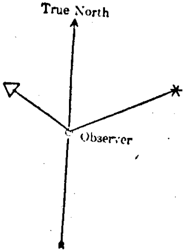
A = Azimuth of S East or West of True North

$$\operatorname{Tan} \tfrac{1}{2} A = \sqrt{\frac{\operatorname{Sin}(s-\Phi)\operatorname{Sin}(s-h)}{\operatorname{Cos} s \operatorname{Cos}(s-p)}}$$

Colog Cos	0.4056453
Colog Cos	0.0014282
Log Sin	9.7266432
Log Sin	9.6991741
Sum 2)	9.8328908
Log Tan ½ A	9.9164454

	°	'	"
½ A	39	31	19.5
A (E or W of North)	79	02	39
Azimuth to S	79	02	39
Minus Angle, Mark to S	98	38	10
True Azimuth to Mark	340	24	29
Grid Correction			
Grid Azimuth to Mark			

Sketch



Computed by A. J. H.
Date of Computation SEPT. 11, 1944

FAS Form No. 11

FAS, Fort Sill, Okla., (6-16-44—24000)—29424

Figure 21. Azimuth of star, altitude method.

59. GENERAL. Much existing control established by such organizations as the United States Coast and Geodetic Survey, the United States Geological Survey, and others is furnished in geographic coordinates and geographic azimuths. These data must be converted to military grid coordinates and grid azimuths before they can be used.

60. MACHINE COMPUTATION. The tables and a full description for computing is contained in "Tables for Transformation of Geographic Coordinates to the Military Grid" published by the War Department, Corps of Engineers, Army Map Service, 1944. These tables can be used for any point on the earth's surface between latitude 0° to 72° either north or south of the equator. Transformation from geographic to grid coordinates is shown on the sample form in figure 22.

61. AZIMUTH. The corrections to reduce geographic azimuths to grid azimuths is given in tables 2 and 3 of the publication referred to in paragraph 60, and are listed for the *X* and *Y* coordinates of any point. A double interpolation is necessary. For points east of the central meridian in the nothern hemisphere, the geographic azimuth is larger; west of the central meridian, the grid azimuth is larger. In the southern hemisphere the opposite is true. The correction may also be computed more accurately by the formula:

$$\text{Correction} = \lambda \sin \phi - 1/12\, \lambda^3 \left(\frac{\pi}{180}\right)^2 \sin 2\phi \cos \phi$$

in which λ = distance in degrees from the central meridian.
ϕ = latitude.

Unless extreme accuracy is desired, the first term of the above equation will give the desired correction.

MACHINE COMPUTATION FORM
for use with
TABLES FOR TRANSFORMATION OF GEOGRAPHIC COORDINATES TO THE MILITARY GRID
POLYCONIC PROJECTION

STATION NO. 10
INDEX FILE 1 — STATE OKLAHOMA — BAND IN
QUAD FORT SILL — ZONE D

Latitude	34° 39' 34.215"	Longitude	98° 24' 18.126"
H (Minutes)	1670.432	Central Meridian	97
ΔH/sec. x secs. (Lat)	- 0.191	$\Delta\lambda$	(-) 1 24 18.126
H	1670.241	$\Delta\lambda'$ (Min. & Dec.)	(-) 84.30210
b (Minutes of $\Delta\lambda$)	(-) 59.3	$(\Delta\lambda')^2$	7106.844
Δ b----x (Dec. Min.)----	.181	V (Minutes)	.138157
b	(-) 59.481	$\Delta V10^6$/sec. x secs. (Lat)	18
a	+ .711	V	.138175
ab	(-) 42.291	Y_o (Minutes)	1 289 952.70
H ($\Delta\lambda'$)	(-) 140 804.824	ΔY_o/sec. x secs. (Lat)	+ 1 153.01
x'	(-) 140 847.115	Y_o	1 291 105.71
	+ 1,000,000	V $(\Delta\lambda')^2$	981.99
X (Yards)	859 152.9	Y (Yards)	1 292 087.7

STATION
INDEX FILE — STATE — BAND
QUAD — ZONE

Latitude	° ' "	Longitude	° ' "
H (Minutes)		Central Meridian	
ΔH/sec. x secs. (Lat)	-	$\Delta\lambda$	
H		$\Delta\lambda'$ (Min. & Dec.)	
b (Minutes of $\Delta\lambda$)		$(\Delta\lambda')^2$	
Δ b----x (Dec. Min.)----		V (Minutes)	
b		$\Delta V10^6$/sec. x secs. (Lat)	
a	+	V	
ab		Y_o (Minutes)	
H ($\Delta\lambda'$)		ΔY_o/sec. x secs. (Lat)	+
x'		Y_o	
	+ 1,000,000	V $(\Delta\lambda')^2$	
X (Yards)		Y (Yards)	

$X = 1{,}000{,}000 + [H(\Delta\lambda') + ab]$
$Y = Y_o + V(\Delta\lambda')^2$

Computed by: MAH
Checked by: WM
Date: 9-5-44

SURVEY FORM NO. 26

Figure 22. Machine computation, transformation geographic coordinates to military grid coordinates.

62. MAGNIFICATION OF SCALE. It should be borne in mind by all surveyors that military grid coordinates are map coordinates and that the magnification of scale (or the stretching of the *Y* coordinate) must be applied before ground distances or the azimuth computation from the coordinates of two points can be used. These corrections are found in table 1 of the "Transformation Tables." (See

par. 60). For an example showing how the starting azimuth and distance are obtained by the survey party before beginning field work, see figure 23. It will be noted that ΔY has been decreased by the scale error since map Y differences are always greater than true ground distances. In order to obtain military or map grid coordinates, the

AZIMUTH AND DISTANCE FROM COORDINATES

Stations		X		Y
From BM 1	(–)	462 445.50	(–)	726 048.70
To BM 2	(+)	461 382.30	(+)	727 762.36
	ΔX	–1 063.20	ΔY	+1 713.66

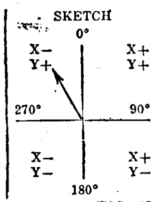
Log ΔX 3.0266150 | Magnification of Scale –5.11
1708.55
–Log ΔY 3.2326277 | True Ground ΔY 1 708.55

Log Tan α 9.7939873 | α 31° 53' 36"

Log ΔX* 3.0266150 | Azimuth 328° 06' 24"

–Log Sin α* 9.7229128

Log D 3.3037022 | D 2012.34 yards



Stations		X		Y
From	(–)		(–)	
To	(+)		(+)	
	ΔX		ΔY	

Log ΔX ______

–Log ΔY ______

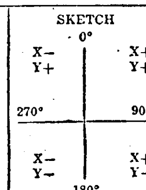
$$\text{Tan } \alpha = \frac{\Delta X}{\Delta Y} \qquad D = \frac{\Delta X}{\text{Sin } \alpha} = \frac{\Delta Y}{\text{Cos } \alpha}$$

Log Tan α ______ | α ______

Log ΔX* ______ | Azimuth ______

–Log Sin α* ______

Log D ______ | D ______ yards



*Note: If ΔX is less than ½ΔY, enter Log ΔY instead of Log ΔX and Log Cos α instead of Log Sin α in these spaces.

FAS Form No. 1 FAS, Fort Sill, Okla., (6-5-44—137,000)—29416

Figure 23. Application of magnification of scale in computing azimuth and distance.

scale error must be added again to each Y coordinate when the computation of the traverse is made. (See fig. 24.)

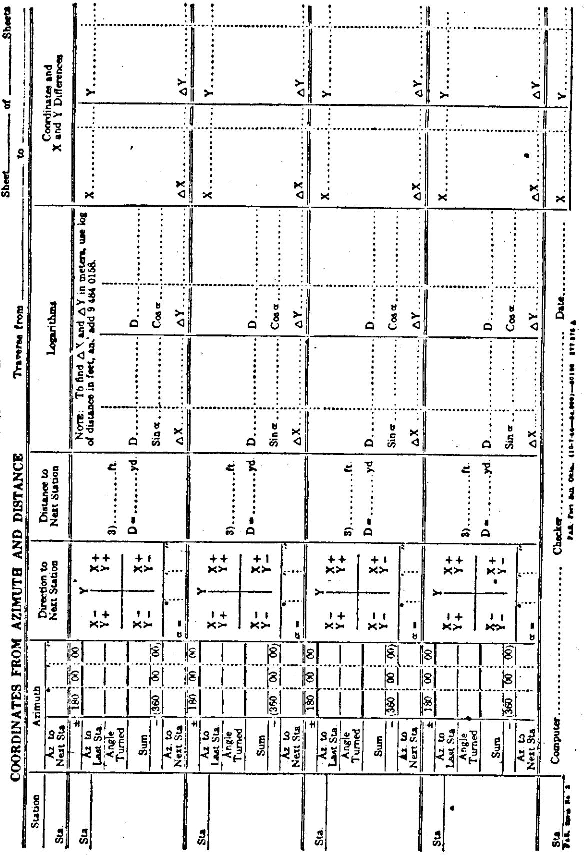


Figure 24. Adding scale error, computation of coordinates.

CHAPTER 5

SOUND RANGING

Section I. GENERAL

63. DEFINITION. Sound ranging is the procedure of locating the source of a sound, such as a gun report or a shell burst, by calculations based upon observations on the propagated sound wave. It is normally employed to locate hostile guns in position and firing, and to adjust the fire of friendly artillery.

64. GENERAL DESCRIPTION. A typical sound ranging installation is shown in figure 25.

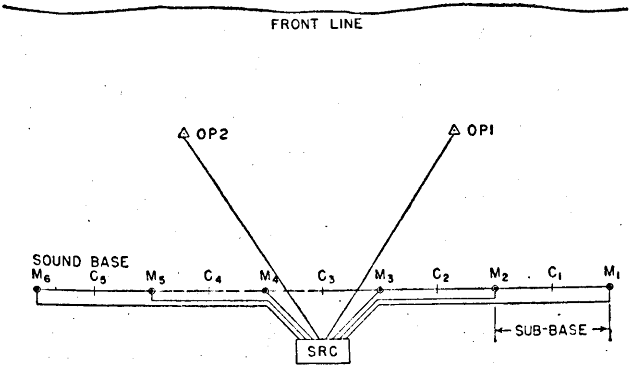


Figure 25. Typical sound ranging installation.

a. Basic theory of sound ranging. The discharge of a gun or burst of a shell causes a sound disturbance, or vibration of the air, lasting for only a fraction of a second. The impulse so produced is propagated through the air in all directions at the same speed as any other sound, 360 to 380 yards per second at average air temperatures.

In still air the sound will arrive at two given points at the same time if their distances from the source are equal, that is, if the source of the sound lies on the perpendicular bisector of the line connecting the two points. For a source in any other position, the arrival times at the points of observation will be different. This difference increases as the source location moves away from the perpendicular bisector, and thus provides a measure of its angular displacement from this line. If two microphones are placed some distance apart and the difference in arrival time of a sound at each microphone is recorded, the direction of a ray which passes very close to the origin of the sound may be determined. Other combinations of two microphones will provide similar rays, and from their intersection the source of sound may be located.

b. Sound base. In practice, a sound wave is detected by an array of four to six microphones, normally spaced at equal intervals (700 to 2,000 or more yards) along a straight line, or under certain conditions along the arc of a circle. However, they may be spaced at unequal intervals along a straight or broken line. Such an array is termed a *sound ranging base* or *sound base.* A straight line segment connecting a pair of adjacent microphones constitutes a *sub-base.*

c. Recording. Each microphone is connected by a wire or radio circuit to the sound recording set located at the *sound ranging central* (*SRC*). The sound impulse received at each microphone is recorded by this equipment on a moving paper tape, or oscillogram. These recorded impulses are called *breaks.* In front of the sound base, at distances of from 1,000 to 2,000 yards, one or two outpost observers are stationed. Either observer, upon hearing a sound of a gun or shell burst must activate the sound ranging apparatus in time to record the sound.

d. Oscillograms. The oscillogram is a paper tape upon which a time scale (1/100-second intervals) and the arrivals of sound impulses are recorded. The time of arrival at each microphone, as measured from an arbitrary zero time, is read from the oscillogram, and the difference between arrival times is computed for each pair of adjacent microphones.

e. Plotting. On the plotting board, the midpoint of each sub-base is plotted and the perpendicular bisector or normal is constructed for use as a reference line. A ray toward the sound is drawn from each midpoint making an angle θ with the reference line, as determined by the relation (par. 83c):

$$\text{Sin } \theta = t/s;$$

in which, sin θ is the sine of the angle θ;

t = the difference between times of arrival at the two microphones, in seconds;

s = the distance between microphones in sound seconds.

One sound second, the distance sound travels in 1 second in air under accepted standard atmospheric conditions, equals 369.2 yards. (See par. 83a.)

The intersection of the plotted rays (or average intersection of a polygon of error) is an approximate location of the source of sound. A more accurate location is obtained by applying curvature and weather-corrections to the measured time intervals. (See pars. 83c and d.)

f. Rapid and deliberate methods. Normally sound ranging installations are accurately surveyed by precise methods. Initially, a sound base may be rapidly installed by hasty survey methods. Such an installation is limited

in application by lack of accuracy of the hasty survey, restricted connecting survey, and communication.

g. The Dodar sound ranging system and its operation and employment in field artillery are described in appendix I.

Section II. SELECTION OF POSITION

65. TYPES OF BASES. a. Number of microphones. The number of microphones installed depends on available time and terrain. A complete installation normally employs five or six microphones. A minimum of four microphones should always be installed to permit three-ray intersection at the target. Increasing the number of microphones increases the number of intersecting rays and improves the reliability of locations.

b. Arrangement of microphones. (1) *Spacing and alignment in a regular base.* The microphones are spaced at uniform intervals along a straight line (*straight base*) or along the arc of a circle concave toward the front (*curved base*). The base is *irregular* if either the spacing or alignment of the microphone is irregular.

(2) *Numbering of Microphones.* Microphones are numbered consecutively from the right when facing the front. They are designated by the symbols, M_1, M_2, etc. The midpoints of the sub-bases are numbered C_1, C_2, etc., consecutively from the right. (See fig. 25.)

(3) *Azimuth of base. The azimuth of a sub-base* is the direction from the lower-numbered to the higher-numbered microphone (from M_1 to M_2, M_3 to M_4, etc.). The azimuth of a straight base is the azimuth of any sub-base. *The azimuth of a curved base* is the azimuth of the *long chord,* or line joining the two extreme, flank microphones.

66. COMPARISON OF BASES. a. Regular base. (1) *General.* The most important advantage of a regular base is that the recorded arrivals of sound at the microphones form an easily recognized pattern on the oscillogram. Anyone accustomed to reading oscillograms on one regular base can read them with equal facility on any regular base; whereas, when there is a change to an irregular base, the oscillogram reader must learn the characteristic patterns of breaks for the new base. Another advantage of a regular base is that standard plotting equipment with previously prepared time scales may be used.

(2) *Curved and straight bases.* The curved base avoids the possible error of plotting a sound source to the front when it is actually to the rear, and facilitates oscillogram reading, because the recorded sound arrivals are grouped more closely together than for a comparable straight base. The curved base requires more computations in survey than does a straight base, and survey of a curved base is often more difficult to accomplish. A curved base covers a somewhat narrower frontage of target area than a straight base.

b. Irregular base. The irregular base is used when the terrain or time available for survey does not permit the installation of a regular base. It results in irregularity in the sequence of breaks, which, when there is considerable artillery activity, may render the oscillograms unreadable. To reduce this effect, microphone positions should be selected to bring the microphones as nearly as possible into alignment, since alignment is more critical than regularity of spacing. The irregular base has the advantage that acoustically favorable locations may be selected for each microphone, which may, under certain conditions of terrain, be the determining factor in choosing the type of base to be used.

67. LENGTH OF BASE. a. The unit of measure for sub-

bases is the sound second, 369.2 yards. (See par. 64e.) Convenient sub-base lengths for rapid installations are 2, and 4 sound seconds. However, other values, preferably multiples of a standard length, may be used. Sub-bases of 4, 4½, 5, and 5½ sound seconds are generally accepted as standard regular bases. Selection of sub-base length is based upon the front to be covered, range to enemy artillery, available terrain, survey, wire laying, and available time.

b. The 2-second base may be used when time is very limited and the difficulties of surveying or laying wire render a longer base impracticable, or when terrain or situation prevents the use of a longer base. The 2-second base is expanded at the first opportunity, usually to a 4-second base, by removing alternate microphones and adding additional microphones at the ends of the base.

c. The base length should be not less than two-thirds the range to the sound source, to attain maximum plotting accuracy. Satisfactory results may be obtained if the base length is not less than one-third of the range. An existing base may be lengthened by using longer sub-bases or by adding microphones.

68. RADIUS OF CURVED BASE. The radius of a curved sound base is the distance in sound seconds from the center of curvature to the arc through the midpoints. The radius to the arc through the microphones is slightly greater. (See fig. 26.) A radius is selected which will place the center of curvature near the center of the area to be observed, or which will fit the base onto the available terrain. Values of sub-base, radius of base, and other elements of standard curved bases for which the mechanical plotting board may be used are given in section XI, chapter 9.

69. LOCATION OF SOUND BASE. a. Location with respect to enemy artillery. The base should be as close as

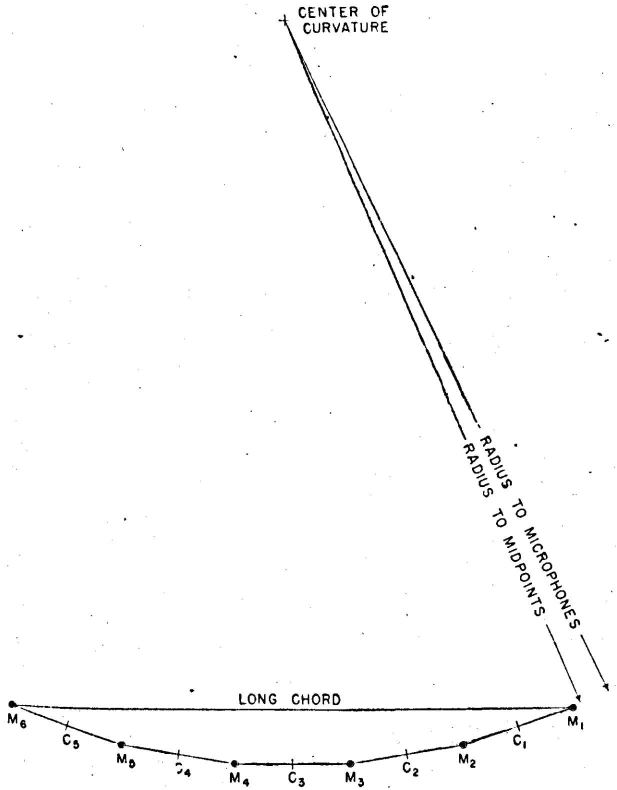


Figure 26. Curved sound base.

possible, consistent with the proper location of the outpost observer, to the area to be observed, and so oriented that the perpendicular bisector of the long chord passes through the approximate center of the area. (See fig. 27.)

To improve sound ranging when a strong flank wind interferes with reception of sound, the sound base should be shifted downwind with respect to the target area, for example, by adding one or more microphones on the down-

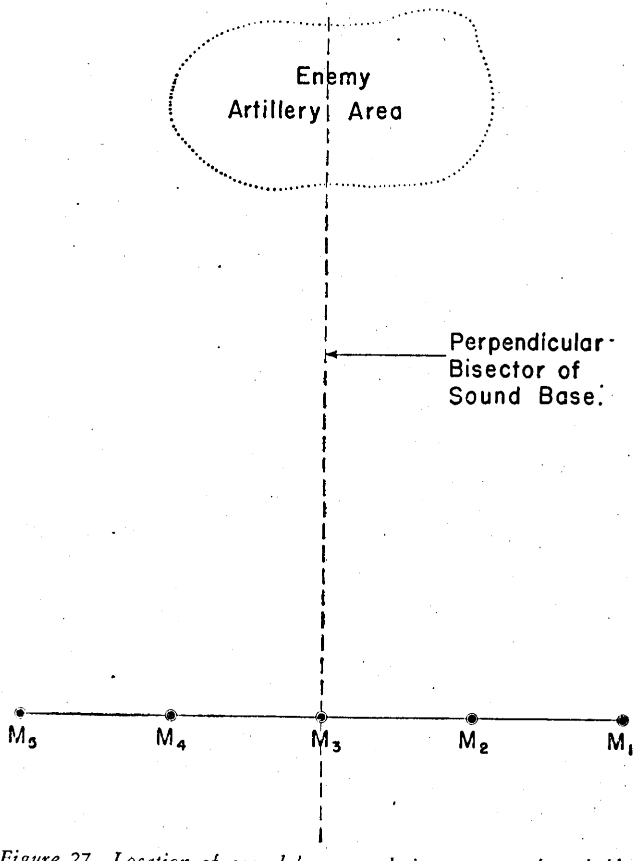


Figure 27. Location of sound base in relation to area of probable location of enemy artillery.

wind end of the base. Crossed bases may be used to increase the width of the sector of observation. If an eight-channel sound recording set is used, a five-microphone base and a four-microphone base, with one common microphone, may be accommodated on one set, as shown in figure 28.

b. Location with respect to front lines. The base

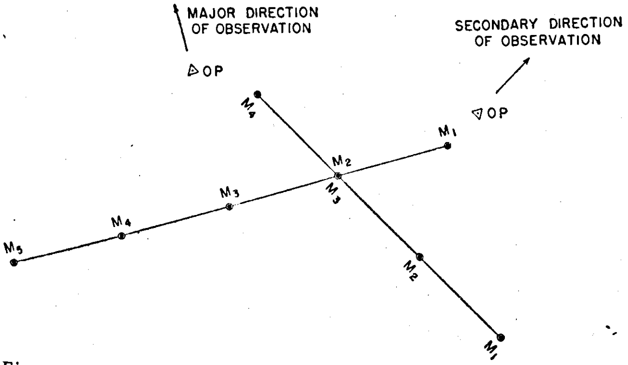


Figure 28. Crossed sound bases. (M_2 of five-microphone primary base is M_3 of four-microphone secondary use.)

should be sufficiently far behind the front lines to enable the outpost observers, upon hearing a sound, to activate the sound recording set before the sound reaches any microphone. (See par. 70.)

c. Location of microphones. (1) Microphones should be located in such positions that they will detect the desired sounds without excessive interference from undesired sounds such as heavy shelling, our own artillery batteries, or heavy motor traffic. Interference from ballistic waves of shells from friendly batteries may be avoided by locating microphones to the rear of these batteries.

(2) Local obstacles, such as low buildings, woods, low banks, or rolling hills, do not materially affect the travel of a low-frequency sound wave. High hills in the direct path between a sound source and microphone may impair the effectiveness of the microphone position or render the microphone totally insensitive. Cliffs, large steep hills, and large buildings near a microphone position may cause a time error as well as disturbing echoes.

(3) If one or more microphones fall in unsuitable locations, the entire base may be displaced a short distance, or

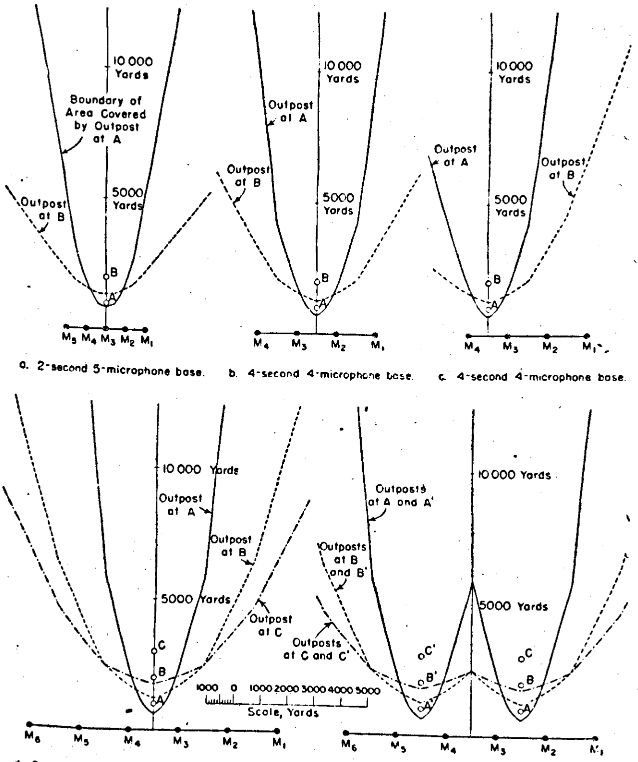
unsuitable locations eliminated by moving individual microphones to more suitable positions.

d. Survey and communication considerations. When possible the base should be located to provide favorable routes for wire laying and favorable terrain for survey. Wire routes, to reduce line maintenance, should avoid use of heavily traveled roads. (See FM 24–20.)

e. Map reconnaissance. If suitable maps are available, a map reconnaissance will facilitate selection of the sound base relative to the target area, combat lines, friendly installations, and terrain features. Transparent templates of standard sound bases to the scale of the map are an aid in determining a suitable position of the base on the ground. The template is laid on the map and shifted until all microphones fall into satisfactory positions. A ground reconnaissance must be made before final selection of microphone positions, to take account of terrain conditions which may be at variance with, or not shown, on available maps.

70. OUTPOST POSITIONS. a. One outpost position should be at least 2-sound seconds (approximately 750 yards) closer to a sound source than any microphone. After the outpost observer detects the sound, some delay, due to the observer's reaction time, occurs before he depresses the starter key, and after the starter key is depressed a delay occurs in the operation of the relays before the sound set begins recording. Figure 29 shows the areas that can be covered from several outpost positions for certain standard bases. For a short base, one outpost position may be sufficient. For a long base, two outposts, one toward either flank of the base, are necessary for complete coverage of a wide front unless a single observer can be placed well forward.

b. The outpost position should be as free as possible from disturbing noises of friendly firing batteries and



a. 2-second 5-microphone base. b. 4-second 4-microphone base. c. 4-second 4-microphone base.

d. 5-second 6-microphone base with one outpost. e. 5-second 6-microphone base with two outposts.

Figure 29. Area of target locations from which sound is heard by the outpost observer at least 2 seconds before its arrival at any microphone.

small arms fire. It should provide cover and concealment for the observers and a covered route of approach. It should be located on a vantage point to provide good visual observation into the enemy area, to permit the observer to estimate accurately the direction to the sound source.

71. SOUND RANGING CENTRAL. To reduce the amount of wire necessary, the sound ranging central should be as

near the center of the sound base as is consistent with security. It should provide cover and concealment for the personnel at the sound ranging central and a covered route of approach. It is normally as close to the base as possible.

Section III. INSTALLATION

72. SURVEY OF SOUND BASE BY RAPID METHODS. a. Internal survey. The internal survey of a sound base consists of locating and marking the microphone positions on the ground in their correct relative positions independently of common survey control. It may be performed by hasty methods, or by precise methods. Survey of sound bases by precise methods is covered in paragraph 73.

(1) *Calibrated wire method.* The starting point for the survey is normally either the center of the base, or a microphone position. It should be marked on the ground with a range pole or a flag. The direction of the base is marked with another range pole or flag 100 to 200 yards distant. Two taping parties, working in opposite directions from the starting point, and maintaining alignment by eye, measure the distance between microphones with fixed lengths of field wire. (A single strand of W–110 field wire, ¼-sound second, 92.3 yards in length, is satisfactory.) No attempt is made to keep the wire horizontal. Alignment is easily maintained by use of range poles or by placing the base on line between two distant terrain features. To avoid errors in total number of tape lengths, tapemen check number of taping pins, or a counter is used. Tapemen should move at double time between tape lengths. This method is best adapted to open terrain; it is rapid, and it is usually the most accurate hasty method of internal survey.

(2) *Inspection and short traverse.* A base may be located by inspection from a map or photomap and by scaling from the map the distances and directions to each microphone

from nearby terrain features which can be identified on both the map and on the ground. A short traverse is run from the terrain feature to the microphone position. The scale of the photomap is determined as in FM 6–40. This method is rapid and is accurate if the map or photomap is accurate and if sufficient recognizable features exist on the map or photomap. It is particularly valuable in rough terrain. It is applicable to either regular or irregular bases. The microphone positions may be located on the sound plotting board by affixing the map or photomap to the plotting board.

(3) *"Shot-in" base.* By the shot-in base method, relative locations of the microphones are obtained from sound ranging determination of the distances from each of two shot points (at which explosive charges are detonated) to each microphone. The base may be shot in when satisfactory maps or photomaps are not available, or when rugged or heavily wooded terrain makes other survey methods difficult or impossible. Microphone positions are selected by inspection on the ground, approximating a straight, regular base.

(*a*) *Shot point at the outpost position.* A shot point is selected near the outpost. The outpost observer makes electrical connections to the outpost line as shown in figure 30. At the sound-recording set, the outpost circuit is temporarily plugged in to a recording channel. When the charge is set and the outpost operator has returned to his telephone, at a safe distance (30 to 50 yards) from the charge, he signals the operator of the sound recording set, "READY." The operator signals, "FIRE" and moves the microphone circuit key to the recording position, and the control key to the over-all test position, which starts the sound set before the charge is fired. The outpost operator waits 5 to 10 seconds and detonates the explosive. A sound record is obtained indicating the instant the charge was fired and the instant of the sound arival at each micro-

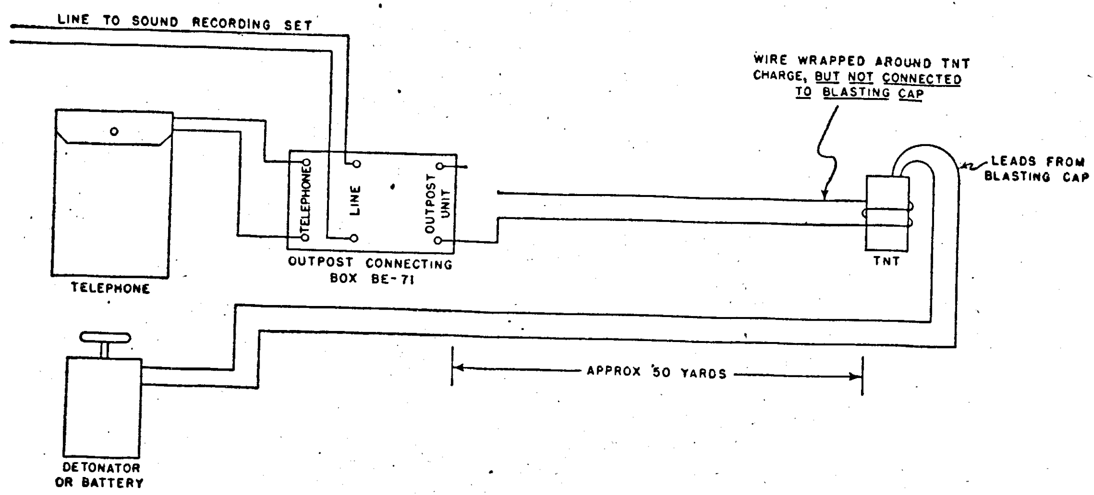


Figure 30. Electrical connections for shooting in a sound base.

phone. The time interval required for the sound to travel from the shot point to each microphone is computed on FAS Form 4 (fig. 31), corrected for temperature and wind as described in (*c*) below, and multiplied by 369.2 to obtain the corresponding distance in yards.

(*b*) *Shot point at microphone position.* At one of the interior microphone positions, the microphone is disconnected and removed to a safe distance and connections made as in figure 30. A sound record is made of an explosive charge fired from within a yard or two of the microphone position by the same procedure as when firing at the outpost position. Distances from the shot point to the other microphones are computed as before from the recorded times of arrival of the sound. (See fig. 31B.) The positions of the microphones are plotted as illustrated by the example in (*d*) below.

(*c*) *Weather corrections.* The temperature correction for each time interval is determined by using the temperature correction chart in the normal manner. (See par. 84b.) Wind corrector M1, which may be set up for any standard length of sub-base, is used in the normal way (par. 84d), except that each sub-base marker is set at the estimated azimuth *from* a microphone *to* the shot point. When difficult terrain makes an estimate of azimuth (to the nearest 200 mils) difficult, it is measured from an uncorrected plot of the microphone positions. The wind corrections are read from the corrector and multiplied by the ratio t/s, in which t is the measured time interval in seconds for the microphone in question, and s is the length in sound seconds of the sub-base for which the corrector is set up.

(*d*) *Illustrative example.* Microphone positions were selected on the ground approximating a five-microphone, 3-second sound base. TNT was fired at point A near the outpost position, and at the position of M_3. Oscillogram

TNT Fired at A — SOUND PLOTTING RECORD

Base: Location S Arbuckle Type 5-Mike Approx 3Sec. Irregular Azimuth ______ Date 5 June 1943

Oscillogram No. ______ Time 1420 Temperature 82 °F Wind: Direction 800 mils Speed 16 mph

Time Readings

Results to (−)					
1	2 M_1 5.806	3 M_2 4.165	4 M_3 4.122	5 M_4 5.809	6 M_5 7.887
Results to (+)	A 0.126	A 0.126	A 0.126	A 0.126	A 0.126

	1 +	1 −	2 +	2 −	3 +	3 −	4 +	4 −	5 +	5 −
Time Interval	5.680		4.039		3.996		5.683		7.761	
Curvature Correction										
Temperature Corr. 0.032/Sec	0.182		0.129		0.128		0.182		0.248	
Wind Correction	0.000		0.032		0.078		0.121		0.161	
Sub-Totals	5.862		4.200		4.202		5.986		8.170	
Subtract										
Corrected Time Interval	5.862		4.200		4.202		5.986		8.170	
Approximate Range Dist.	2164		1550		1551		2210		3016	

Coordinates: X ______ Y ______ Accuracy ______ yards Caliber ______ File No. ______

Area Shelled ______ No. of Pieces ______ Time Reported ______ Conc. No.

FAB Form No. 6

FAB Fort Sill, Okla. (9-19-44—15,000)—50035

(A)

TNT Fired at M_3 — SOUND PLOTTING RECORD

Base: Location S. Arbuckle Type 5-Mike Approx 3Sec. Irregular Azimuth ______ Date 5 June 194

Oscillogram No. ______ Time 1425 Temperature 82 °F Wind: Direction 800 mils Speed 16 mph

Time Readings

Results to (−)					
1	2 M_1 5.936	3 M_2 3.163	4 M_4 3.131	5 M_5 5.669	6
Results to (+)	M_3 0.230	M_3 0.230	M_3 0.230	M_3 0.230	

	1 +	1 −	2 +	2 −	3 +	3 −	4 +	4 −	5 +	5 −
Time Interval	5.706		2.933		2.901		5.439			
Curvature Correction										
Temperature Corr. 0.032/ Sec.	0.188		0.094		0.093		0.174			
Wind Correction		0.086		0.044	0.044		0.082			
Sub-Totals	5.894	0.086	3.027	0.044	3.038		5.695			
Subtract	0.086		0.044							
Corrected Time Interval	5.808		2.983		3.038		5.695			
Approximate Range Dist.	2144		1101		1122		2103			

Coordinates: X ______ Y ______ Accuracy ______ yards Caliber ______ File No. ______

Area Shelled ______ No. of Pieces ______ Time Reported ______ Conc. No. ______

FAB Form No. 6

FAB Fort Sill, Okla. (9-19-44—15,000)—50035

(B)

Figure 31. Computing form for "shot-in" sound base.

readings for each round were recorded. (See fig. 31.) Time intervals were computed, and temperatures and wind corrections were applied as shown. The wind corrections were computed as follows, using the azimuth from each microphone to the sound source which was estimated to the nearest 200 mils. The wind corrector was set up for a 4-second sub-base.

TNT FIRED AT *A*

Microphone	Estimated azimuth to TNT		Reading from corrector		Ratio t/s		Wind correction
M_1	5,600		0.000	x	1.420	=	0.000
M_2	6,000	+	0.032	x	1.010	=	+0.032
M_3	400	+	0.078	x	0.999	=	+0.078
M_4	800	+	0.085	x	1.421	=	+0.121
M_5	1,000	+	0.083	x	1.940	=	+0.161

TNT FIRED AT M_3

M_1	4,800	–	0.060	x	1.428	=	–0.086
M_2	4,800	–	0.060	x	0.733	=	–0.044
M_4	1,600	+	0.060	x	0.723	=	+0.044
M_5	1,600	+	0.060	x	1.360	=	+0.082

Each corrected time interval was multiplied by 369.2 to determine the corresponding distance from the shot point to the microphone, which was then recorded as shown.

A line was drawn near the lower edge of the sound plotting chart to represent the line of sub-base M_2—M_3. (See fig. 32.) A point on this line was arbitrarily selected as the position of M_3. A point on the line plotted to scale at the computed distance of 1,101 yards (fig. 31) to the right of M_3, locates M_2. Point *A* was located by the intersection of arcs from M_3 and M_2 at radii of 1,551 and 1,550 yards, respectively. Each remaining microphone was located by the intersection of arcs of radii equal to the computed distances from M_3 and point *A*.

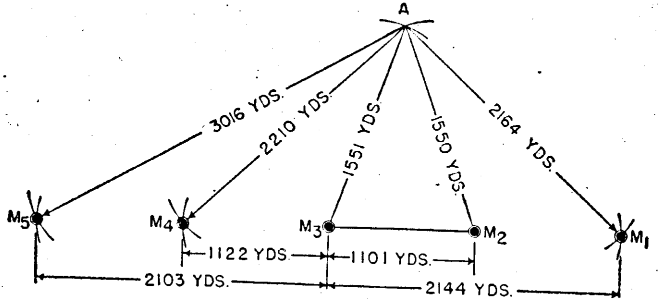


Figure 32. Graphical construction of "shot-in" sound base.

b. Connecting survey. (1) The connecting survey for a sound base is the survey performed to determine the orientation and position of the base relative to other installations on a common grid. In a hasty installation, survey control is frequently not completed until the internal survey is improved. The azimuth of the base is usually determined by means of a declinated aiming circle or compass. The location of the base on the grid may be determined by resection, by inspection and short traverse from a known point, or by firing.

(2) Whether or not a common grid has been established, the sound base may be registered by the supported firing unit on selected base (check) points, as described in paragraph 91. The plotting procedure used is similar to that described in paragraph 115.

c. Improving survey of a sound base. Internal survey performed by hasty methods is improved as described in chapter 4. During the improvement of the survey, the base may be expanded as desired and an irregular base converted to a regular base. The sound base is placed on the common grid by connecting the internal survey of the base to established survey control.

73. SURVEY OF BASE BY PRECISE METHODS. a. General. The microphone positions of a sound base will be located, whenever possible, by survey methods described in chapter 4.

b. Regular base. The coordinates of a point on the sound base (usually a microphone position or the center of the base) and the azimuth of the base, from which the coordinates of each microphone position are computed, may be determined from a map or photomap. The microphones are then located on the ground at their computed positions by survey. If survey control is available at a point on or near the base, the internal survey may start from this point. If survey control is not available, the internal survey is started from a convenient point assigned arbitrary coordinates. Conversion to common grid coordinates is made as soon as possible. If sufficient survey control points exist in the vicinity of the sound base, a short traverse may be run to each microphone position from the nearest control point. (See fig. 33.)

(1) *Straight base.* (*a*) *Traverse.* The internal survey of a straight base may be accomplished by traversing along the line of the base. Usually two parties, each starting at the selected common starting point, work in opposite directions. If the terrain or an exposed position does not permit the survey parties to follow along the line of the base, it may be necessary to select traverse routes along accessible trails in the vicinity which are less exposed to enemy action or which provide routes around terrain obstacles. The coordinates of each point are computed as the traverse progresses. The distance and direction from traverse points to microphone positions are determined.

(*b*) *Triangulation.* The terrain and existing survey control may permit the use of triangulation to facilitate survey of the base.

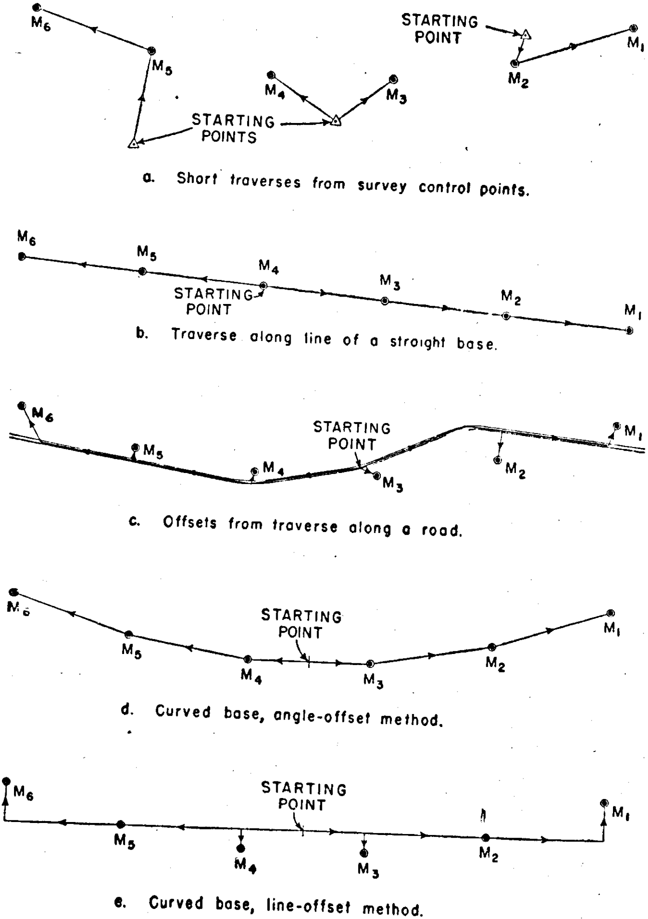


Figure 33. Methods of surveying sound bases.

(2) *Curved base.* The concave side of the curved base faces the target area. The internal survey may be accomplished by *the line offset* method, *the angle offset* method, traverse methods, or a combination of triangulation and traverse.

(*a*) *Line offset method* (fig. 33). By the line offset method each microphone is located by right-angle offsets from a straight line traverse through microphones numbered 2 and 5. This method permits ready shifting of the entire base in a direction parallel to the long chord in the event that the position of any microphone initially falls in an unfavorable location, and affords less opportunity for survey errors; however, it is limited to terrain suitable for a straight line traverse.

(*b*) *Angle offset method* (fig. 33). By the angle offset method each microphone is located by a direct traverse from microphone to microphone, and taping a constant distance and turning a constant angle for the new direction at each microphone position. This method does not facilitate shifting the base in the event it becomes necessary, and any error in the location of one microphone is reflected in the location of all subsequent microphones. It is limited to use in favorable terrain in much the same manner as the line offset method.

(*c*) *Traverse methods.* If neither the line offset method nor the angle offset method is appropriate, the microphones may be located by traverse to each microphone position over the most accessible route afforded by the terrain.

(*d*) *Triangulation.* The terrain and existing survey control may permit the use of triangulation to facilitate the survey of the base.

c. Irregular base. Microphone positions are selected by map inspection and reconnaissance, and selection of final locations of microphones may precede the determination of their coordinates by survey. Usually, microphones will be located by traverse. On suitable terrain, survey may be accomplished by triangulation, or combination of triangulation and traverse.

74. COMPUTATION OF SOUND BASE. a. Regular base. Data necessary to compute the coordinates of each microphone position of a regular base are: (1) length of sub-base, (2) number of microphones, (3) radius of base, if curved, (4) coordinates of one point on the base, and (5) the azimuth of the base. Computations should be made *independently* by two computers to provide a check. Computers should construct a rough sketch, showing the orientation of the base relative to the grid, with microphones properly numbered, as an aid in avoiding gross errors. FAS Form 2 should be used for the computations.

(1) *Straight base.* An example of the computations for a 4-second, six-microphone, straight-base, azimuth 278° 15′ 00″, coordinates of M_3, 284,044.0—182,385.6 is shown in figure 34. The length of sub-base (M_3 to M_4) is tabulated in section XII, chapter 9, as 1476.8 yards. Completing the computations indicated on the form ΔX is determined as minus 1461.5 yards and ΔY as plus 211.9 yards. Thus, in moving from M_3 to M_4, or from any microphone to the next higher-numbered microphone, the X coordinate is decreased by 1461.5 yards and the Y coordinate is increased by 211.9 yards.

Starting with the coordinates of M_3, increments are added for each microphone up to M_6, as follows:

	X	Y
Coordinates of M_3	284,044.0	182,385.6
Difference, M_3 to M_4	−1461.5	+211.9
Coordinates of M_4	282,582.5	182,597.5
Difference, M_4 to M_5	−1461.5	+211.9
Coordinates of M_5	281,121.0	182,809.4
Difference, M_5 to M_6	−1461.5	+211.9
Coordinates of M_6	279,659.5	183,021.3

Sheet 1 of 1 Sheets

Traverse from ______ to ______

COORDINATES FROM AZIMUTH AND DISTANCE

Station	Azimuth	°	′	″	Direction to Next Station	Distance to Next Station	Logarithms		Coordinates and X and Y Differences	
Sta.	Az. to Next Sta.									
	±	180	00	00			NOTE: To find ΔX and ΔY in meters, use log of distance in feet, and add 9.484 0158.		X 2840440	Y 1823856
Sta. M_3	Az. to Last Sta.				X− Y+ / Y / X+ Y+ / M_4 M_3 / X− Y− / X+ Y−	3) .... ft.				
	Angle Turned					D-14768 yd.	D 3 1693217	D 3 1693217		
	Sum						Sin α 9 9954822	Cos α 9 1568296		
	−	(360	00	00)						
	Az. to Next Sta.	278	15	00	α −81° 45′ 00″		ΔX 3 1648039	ΔY 2 3261513	ΔX −14615	ΔY +2119
	±	180	00	00					X 2825825	Y 1825975
Sta. M_4	Az. to Last Sta.				X− Y+ / Y / X+ Y+	3)				
	Angle									

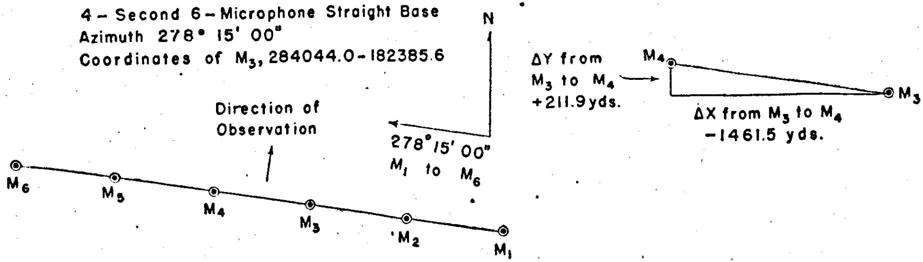


Figure 34. Sketch and computation for a straight sound base.

In moving in the opposite direction, from M_3 to M_1, the same increments are applied with opposite signs.

	X	Y
Coordinates of M_3........................	284,044.0	182,385.6
Difference, M_3 to M_2.....................	+1461.5	−211.9
Coordinates of M_2........................	285,505.5	182,173.7
Difference, M_2 to M_1.....................	+1461.5	−211.9
Coordinates of M_1........................	286,967.0	181,961.8

As a check, the difference between the X coordinates of M_1 and M_6 should be five times ΔX, and the difference between the Y coordinates of M_1 and M_6 should be five times ΔY. If the computation begins with the coordinates of the midpoint of the base, C_3, the procedure is the same with the exception that the first increment, from C_3 to M_4 and from C_3 to M_3, is one-half that for the sub-base of 1476.8 yards.

(2) *Curved base.* Since each sub-base of a curved base has a different azimuth, the increments ΔX and ΔY must be computed for each sub-base. The offset angle β is the difference in azimuth between any two adjacent sub-bases. This angle, when added to the azimuth of any sub-base, gives the azimuth of the next higher-numbered sub-base; when subtracted, the result is the azimuth of the next lower-numbered sub-base. For a 5-second curved base with a radius of 30 seconds, section XI, chapter 9, lists the offset angle β as 9° 31′ 38″. If the azimuth of the base (and of sub-base M_3 to M_4) is 73° 14′ 12″ the azimuths of the other sub-bases are computed as follows:

$$\text{Azimuth } M_3 \text{ to } M_4 = 73^\circ\ 14'\ 12''$$
$$+\beta = \underline{+9^\circ\ 31'\ 38''}$$
$$\text{Azimuth } M_4 \text{ to } M_5 = 82^\circ\ 45'\ 50''$$
$$+\beta = \underline{+9^\circ\ 31'\ 38''}$$

$$\begin{aligned}
\text{Azimuth } M_5 \text{ to } M_6 &= 92^\circ\, 17'\, 28'' \\
\text{Azimuth } M_3 \text{ to } M_4 &= 73^\circ\, 14'\, 12'' \\
-\beta &= \underline{-9^\circ\, 31'\, 38''} \\
\text{Azimuth } M_2 \text{ to } M_3 &= 63^\circ\, 42'\, 34'' \\
-\beta &= \underline{-9^\circ\, 31'\, 38''} \\
\text{Azimuth } M_1 \text{ to } M_2 &= 54^\circ\, 10'\, 56''
\end{aligned}$$

As a check, the azimuth of sub-base M_1 to M_2 plus 4 β equals the azimuth of sub-base M_5 to M_6.

Computations for this base are shown in figure 35. The coordinates of M_3 are given as 277,740.5—192,713.2. Section XII, chapter 9, lists the length of the 5-second sub-base as 1846.0 yards. Note that in progressing from M_3 to M_6, as shown in the first three computing forms of figure 35(A) the azimuths used are as computed above. The azimuth used in proceeding from M_3 to M_2 (from the higher-numbered microphone) is the back azimuth of M_2 to M_3. Similarly, the azimuth from M_2 to M_1 is opposite that shown above for M_1 to M_2. (See fig. 35(B).)

A check on the computations is also shown in figure 35(B). Starting with the computed coordinates of M_1, and the distance and azimuth to M_6, the coordinates of M_6 are computed. The distance from M_1 to M_6 (length of the long chord L) is listed in section XI, chapter 9.

b. Irregular base. The coordinates of the microphones of an irregular base are computed as the stations in a traverse.

75. INSTALLING WIRE. a. Complete sound ranging wire installations consist of a circuit from each microphone and each outpost to the sound recording set. One outpost circuit should be completed by the time four microphones are connected, in order to effect early operation of the base.

b. The technique of field wire installation is prescribed in FM 24–20. In laying microphone lines, care must be

COORDINATES FROM AZIMUTH AND DISTANCE — Traverse from .... to .... — Sheet 1 of 2 Sheets

NOTE: To find ΔX and ΔY in meters, use log of distance in feet, and add 9.484 0158.

Station	Az to Next Sta	Direction to Next Station	Distance to Next Station	Log D	Sin α	Log ΔX	Log D	Cos α	Log ΔY	ΔX	ΔY	X	Y
Sta M_3	73 14 12	α -73 14 12	D=18460 yd	32662317	99811408	32473725	32662317	94600240	27262557	+17676	+5324	2777405	1927132
Sta M_4	82 45 50	α -82 45 50	D=18460 yd	32662317	99965272	32627589	32662317	91002275	23664592	+18313	+2325	2795081	1932456
Sta M_5	92 17 28	α -87 42 32	D=18460 yd	32662317	99996527	32658844	32662317	86018077	18680394	+18445	-738	2813394	1934781
Sta M_6												2831839	1934043

Computer .... Checker .... Date ....

(A)

COORDINATES FROM AZIMUTH AND DISTANCE — Traverse from .... to .... — Sheet 2 of 2 Sheets

NOTE: To find ΔX and ΔY in meters, use log of distance in feet, and add 9.484 0158.

Station	Az to Next Sta	Direction to Next Station	Distance to Next Station	Log D	Sin α	Log ΔX	Log D	Cos α	Log ΔY	ΔX	ΔY	X	Y
Sta M_3	243 42 34	α -63 42 34	D=18460 yd	32662317	99525791	32188108	32662317	96463287	29125604	-16550	-8176	2777405	1927132
Sta M_2	234 10 56	α -54 10 56	D=18460 yd	32662317	99089578	31751895	32662317	97673112	30335429	-14969	-10803	2760855	1918956
Sta M_1												2745886	1908153
CHECK COMPUTATION													
Sta M_1	73 14 12	α -73 14 12	D=897678 yd	39531206	99811408	39342614	39531206	94600240	34131446	+85953	+25891	2745886	1908153
Sta M_6												2831839	1934044

Computer .... Checker .... Date ....

(B)

Figure 35. Computation of a curved sound base.

exercised to avoid damaging wire insulation. Splices must be carefully made to avoid excessive line resistance and must be well insulated to prevent excessive leakage or

possible shorts. Lines which would operate satisfactorily as telephone circuits may be inoperative as microphone lines. The latter usually operate at a potential of 90 to 135 volts, hence their efficiency is seriously impaired by low insulation resistance.

c. Microphone lines are normally laid from the sound-ranging central to the microphone positions. The microphones of a regular base frequently can be spotted by a wire laying party before survey reaches their positions. Section XII, chapter 9, lists the lengths of standard sub-bases expressed in miles to facilitate use of odometers by the wire parties in spotting microphone positions. Upon reaching the approximate microphone position, sufficient slack must be provided to allow enough line to move the microphone from its spotted position to its surveyed position. The microphone is installed after the survey has been completed.

76. INSTALLING MICROPHONES. a. Procedure. Microphones are serviced by sound ranging personnel, but may be installed by communication personnel. Upon arrival of a wire laying vehicle at a microphone position, the wire is cut, tied in, and tested. Sufficient slack is coiled at the position. A microphone is then connected to the line, and tested. If the line and microphone are both found to be operative, one wireman is left with a telephone and the necessary equipment to complete the installation. The wire party then proceeds to lay other wire circuits.

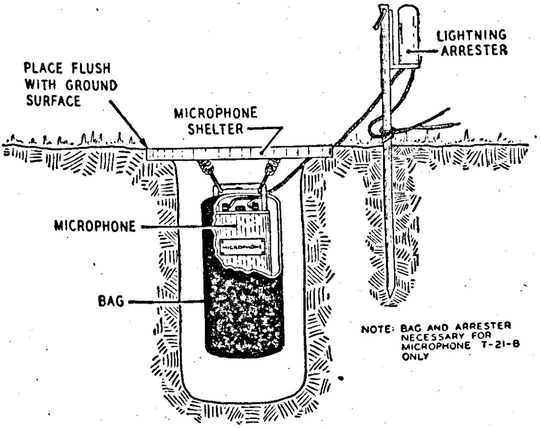
b. Emplacing microphones. The microphone should be installed so as to be shielded as much as possible from the direct effects of wind and other disturbances. The microphone illustrated in figure 36 is provided with a waterproof (rubber) bag, to prevent it from shorting out because of water in the microphone hole. Other types of microphones do not require such protection. A microphone

may be suspended from a microphone shelter on the springs provided or by other appropriate means. (See fig. 36.) The standard shelter is a flat canvas cover on a metal frame from which the microphone is suspended in a hole in the ground, as shown in figure 36(a), or, if the character of the ground is such that a hole cannot be dug, a support as shown in figure 36(b) may be built of stones, earth, brush, or similar material. Where terrain does not permit emplacement as indicated in either figure 36(a) or 36(b), the microphone may be suspended from a tripod. (See fig. 37.) Regardless of the method of emplacement, the microphone must be sheltered from the wind.

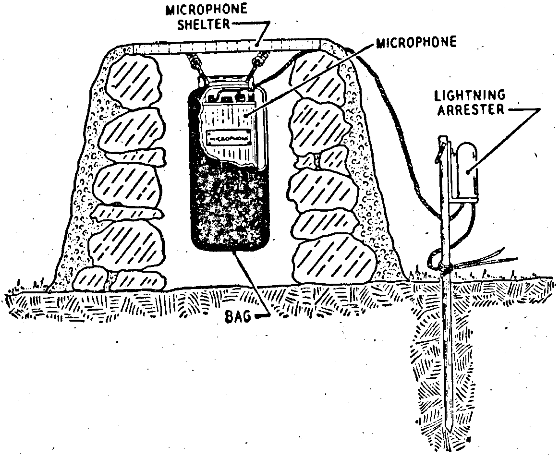
c. Connecting telephone to microphone circuit. A telephone may be connected to any microphone circuit as may be required for communication with the sound ranging central. It must be disconnected when the microphone is being tested, as the microphone is inoperative when the telephone is connected unless the connection is made through an outpost connecting box or other capacitor unit. Telephones must not be connected to a microphone circuit when sound ranging is in progress.

d. Avoiding shocks. When the microphone circuit key on the sound recording set is in the *Oscillogram* or recording position, a high potential is applied to the microphone line. To avoid shocking the wireman, the key is left in the *Telephone* position until the wireman calls for a microphone test. It is then moved to the recording position *after* the wireman has had time to disconnect his telephone, and is left in that position only for a short prearranged period of time.

e. Two microphones on one line. In an emergency, two microphones may be temporarily connected to a single microphone circuit. The first microphone is connected in



a. NORMAL INSTALLATION



b. ROCKY GROUND INSTALLATION

Figure 36. Emplacement of a microphone.

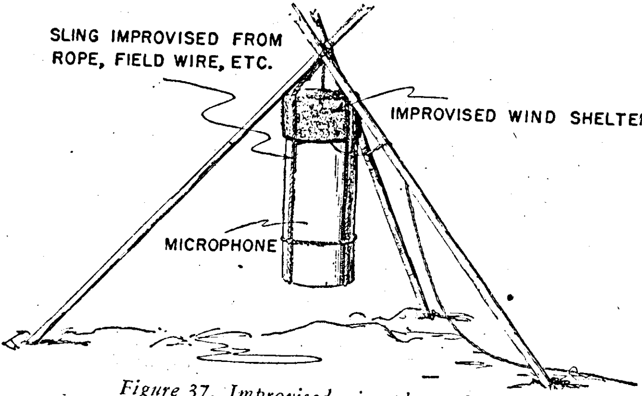


Figure 37. Improvised microphone shelter.

the normal manner. When the second microphone is connected, a polarity test must be made at the sound recording set. If this test indicates that the polarity of the second microphone is reversed, the leads at the microphone must be changed.

f. Emplacing microphones after resurvey. The position of a microphone will not be changed without notice to the sound ranging central. It is preferable that all necessary shifting of microphone positions are made simultaneously to avoid prolonged periods of "out of action" and to achieve minimum interruption of sound ranging. If long moves are necessary, it is possible to install a microphone at the new position and, from it lay wire back to the old position. This permits the change-over to be made with a minimum loss of time; the line from the microphone at the old position is disconnected and spliced into the new line.

77. RADIO SOUND DATA TRANSMISSION SYSTEMS.

a. General. It may be desirable to install a sound base in which some or all of the wire circuits are replaced by a

radio sound data transmission system. A description of equipment for this purpose, and instructions for its operation, may be found in the appropriate Technical Manual.

b. Employment. The sound data transmission system may serve as a secondary, alternate means or as a primary means of communication. Under adverse conditions of weather or terrain, the installation of wire circuits may be delayed, or it may be impossible to install wire circuits. Also, intense artillery fire or mechanized vehicles may make maintenance of wire circuits impossible. Under such conditions, the system may provide communication between microphones and sound central, thereby permitting operation of a sound base which would otherwise be useless. The sound data transmission system will facilitate rapid occupation of position and displacement; however, in general, such communication is less secure than wire and subject to the same uncertainties normally encountered in any radio operation. Interference may obscure the oscillogram patterns and prohibit operation entirely; consequently, wire circuits must always be provided as soon as time permits.

c. Installations. The number of microphones operated on the radio system depends upon the situation. It will usually be possible to lay at least one wire circuit to the microphone nearest the sound ranging central, while radio communication is being established to the other microphones. When the terrain and tactical situation permit, the radio unit for each microphone may be installed in a vehicle, and the microphone operated from the vehicle in a nearby emplacement. Microphones are installed as described in paragraph 76*b*, and connected by field wire to the radio units.

78. ORGANIZATION OF SOUND RANGING CENTRAL. The sound plotting group should be located near the re-

cording set to permit recorders and plotters to work together. In setting up the sound recording equipment, communication circuits should be connected and tested

Figure 38. Sound-recording set, dug in.

Figure 39. Sound ranging plotting.

promptly. Sound plotting equipment is prepared for operation and the sound ranging central is organized in the most expeditious manner consistent with the time available. (See figs. 38 and 39.) In rapidly moving situations, the sound recording set may be installed in a small vehicle or trailer.

Section IV. OPERATIONS

79. OPERATIONS OF OUTPOST OBSERVERS. In a rapid installation, the outpost observer may lay his own wire circuit from the recording set to his outpost position. If the base is to be shot in, he must detonate an explosive at a point near the outpost, as described in paragraph 72*a*. Immediately upon arrival at the outpost position, the observer installs his equipment. He should be provided with an azimuth indicator (a board or transparency with a 6,400-mil protractor scale and a rotating arm) which he orients immediately by map inspection or compass. He listens for the sounds of guns or shell bursts to be recorded, starts the sound-recording set, and stops it when directed to do so by the sound recorder. He reports the apparent azimuth, estimated range to the gun and its suspected caliber to the sound ranging central, and the number, distribution, and activity of enemy guns. He reports all other activity he observes. The outpost observer must be carefully trained and must have extensive experience. The effectiveness of sound ranging is directly proportional to his ability.

80. RECORDING. a. General. The technique of operating and maintaining the sound recording equipment is described in the appropriate Technical Manuals.

b. Sound-ranging adjustment. To record the shell bursts in a sound-ranging adjustment, the sound recording set should be started by the operator, not the outpost ob-

server. To reduce wastage of sensitized paper, due allowance should be made for the time of flight of the projectile and the estimated time of travel of the sound from the point of burst to the nearest microphone.

81. OSCILLOGRAMS. a. General. Oscillograms are obtained by recording sound arrivals either electrically or photographically on a paper tape, at a rate of approximately 6 inches per second.

b. Galvanometer traces. (1) On the oscillogram, a number of horizontal lines are traced, one corresponding to each microphone installed. Normally the upper line is traced by the galvanometer connected to microphone number 1, the second by that connected to microphone number 2, etc.

(2) When no sound or wind strikes a microphone, the corresponding galvanometer trace is recorded as a straight line. Wind causes the line to waver from its normal position. When the sound of a gun reaches a microphone, an electric impulse is communicated to a galvanometer producing a wavy line or break. (See fig. 40.) The point at which the trace first departs from its straight line part, or *zero line,* is the *initial break.* With sound ranging equipment now in use, the initial break is always downward for a sound beginning with a compressional wave, as is produced by a gun or bursting shell. The low and high points on the trace are termed respectively *valleys* and *crests.* The total elapsed time from the initial break until the trace has made one excursion downward and back, and one excursion upward and back to the zero line (one *wave length*), is the *period* of the sound wave. The configuration on the oscillogram of the breaks produced on the several traces by one sound wave, as it arrives in turn at the various microphones, is the *pattern of arrivals.* The pattern

may be made more apparent if a smooth curve, connecting the initial breaks, is drawn on the oscillogram.

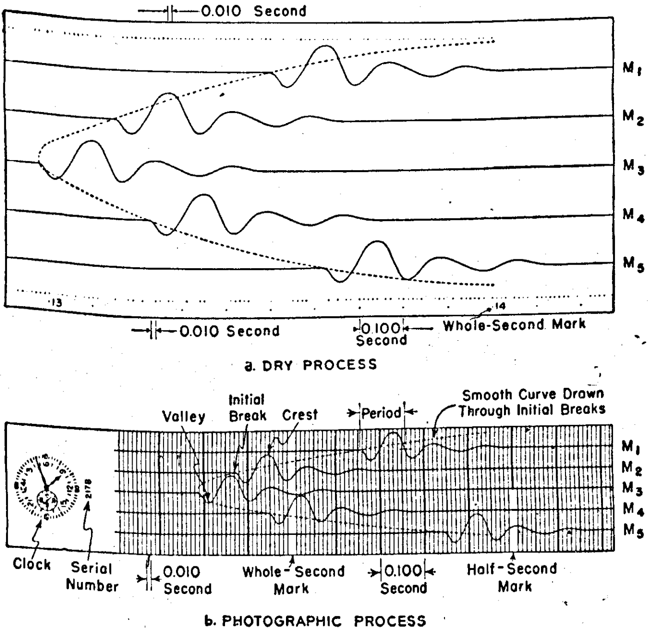


Figure 40. Oscillograms.

c. Dry recording process. A sound recording set which utilizes a dry recording process is shown in figure 41. Galvanometer traces are recorded on the oscillogram (fig. 40 (a) by electric styli. Time intervals are recorded by three additional styli and a timing stamp. Two rows of dots, at intervals of 0.010 second, are marked near and parallel to each edge of the strip. Just below and synchronized with the lower row of 0.010-second dots is a similar row of dots at 0.100-second intervals. The timing stamp, which is synchronized with the 0.100-second stylus, prints consecutive numbers at 1-second intervals along the lower

edge of the oscillogram. Since no identification data are recorded, a serial number and the time the record was made, along with any additional identification data and any information reported by the outpost observer, should be noted on the back of the oscillogram.

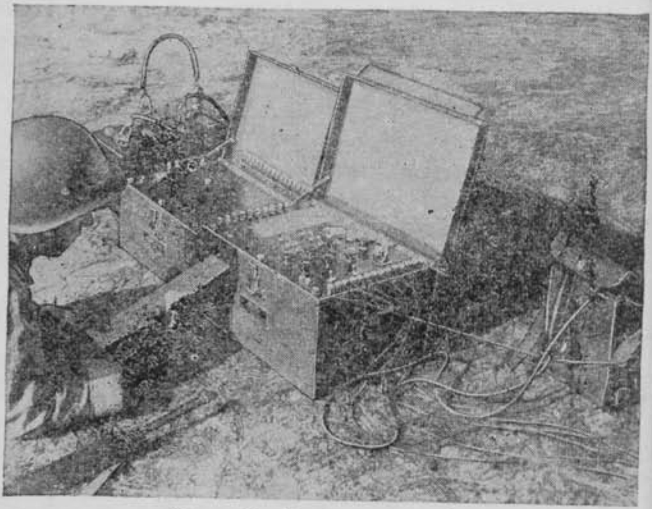


Figure 41. Dry process recorder.

d. Photographic recording process. Oscillograms produced by photographic process sound recording sets (fig. 40(*b*)) are taken from the oscillograph completely developed and partially fixed. The fixing process may be completed by an additional few seconds immersion in appropriate chemicals. Records may be read while wet, then dried for subsequent file. Both the galvanometer traces (horizontal lines) and the timing lines (vertical lines), as well as a serial number and the photograph of a 24-hour clock are recorded photographically on the oscillogram. With the identification panel on the left, as in figure 40, time is measured from left to right. The distance between

adjacent lines represents 0.010 second. Each tenth line is heavy, making the interval between heavy lines 0.100 second. Each fifth heavy line is only half the normal length, indicating half-seconds, and each tenth heavy line is omitted, indicating full seconds.

82. OSCILLOGRAM READING. a. Procedure. Selection of the desired pattern of breaks is the first step in reading an oscillogram. If there is only one pattern this is a simple operation. When there are several patterns, which is frequently the case in combat, the oscillogram reader must have a mental picture of the desired pattern in order to isolate it from the others. The oscillogram should be laid out carefully on a table or flat surface, with the end first emerging from the recording set to the left. The first whole second mark to the left of the first break is selected as the initial point or zero time. Each successive second mark to the right is numbered in sequence to the end of the pattern. (See fig. 40.) With this scale as a basis, the oscillogram reader determines the time of the initial break for each trace. Whole seconds, tenths, and hundredths are read directly, and thousandths are estimated by interpolating between the dots or lines. Thus in figure 40(b), the times are read as follows:

M_1: 1.154

M_2: 0.870

M_3: 0.783

M_4: 0.945

M_5: 1.338

b. Indistinct breaks. (1) It is preferable to read each trace at the initial break when it can be identified. In some cases the trace may break so gradually from the zero line that the initial break is difficult to determine. This condi-

tion is aggravated if wind interference or other disturbances are superimposed on the trace.

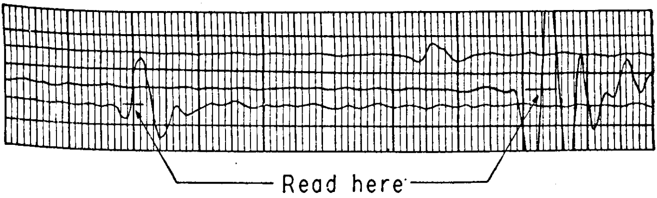
(2) When it is impossible to locate the initial break accurately, other points along the trace may be read provided that the corresponding points on all breaks of the pattern are read.

(3) When the wave shapes appear to be similar, and the initial break cannot be read, a point at which the trace crosses the zero line may be read as shown in figure 42 (a). The zero line may be extended by use of a straightedge to aid in locating this point accurately. The corresponding crossovers must be read on all traces.

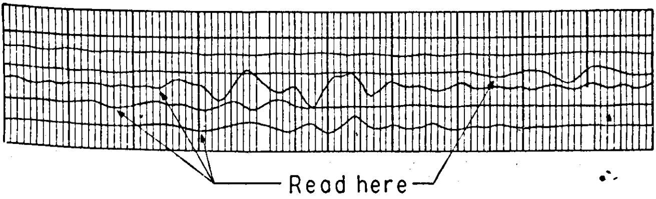
(4) When the wave shapes appear to be similar and the initial break cannot be read, and a wavering zero line also makes it impossible to locate the crossover points, the waves may be read at corresponding crests or valleys, as shown in figure 42 (b). It is least desirable to read these points as they are usually shifted in phase by superimposed disturbances more than the crossover points.

(5) Occasionally, all loops of a wave as received at one microphone are quite distinct, but the first loop or two as received at another microphone are of relatively low amplitude and might be overlooked, with the result that the time read from the break on the second trace would be read too late. (See fig. 42 (c).) To avoid this error, the oscillogram reader should examine and compare several traces of a pattern to insure that he actually reads corresponding points on all traces.

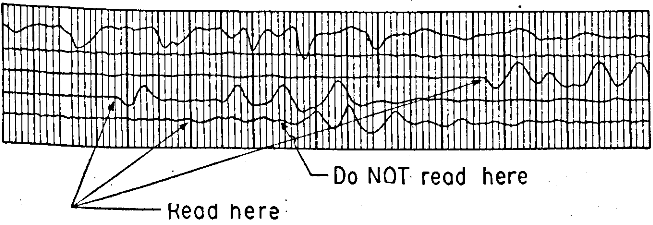
c. Typical patterns. (1) An experienced oscillogram reader associates, in his mind, the location of a sound source, in relation to the base, with the corresponding pattern of breaks produced on the oscillogram. Several typical patterns for a regular straight sound base and the corresponding locations of the sound source are shown in figure 43. For



a. Initial break obscured



b. Initial break and zero line obscured



c. First loops indistinct on one trace

Figure 42. Reading indistinct breaks.

each pattern, a smooth curve can be drawn connecting the initial breaks. In each case the curve is concave to the right. It is symmetrical if the sound source is to the direct front, skewed in one direction with its lower branch elongated when the sound source is to the right front, and skewed in the other direction with its upper branch elongated if it is to the left front. The over-all length of the pattern decreases as the range increases.

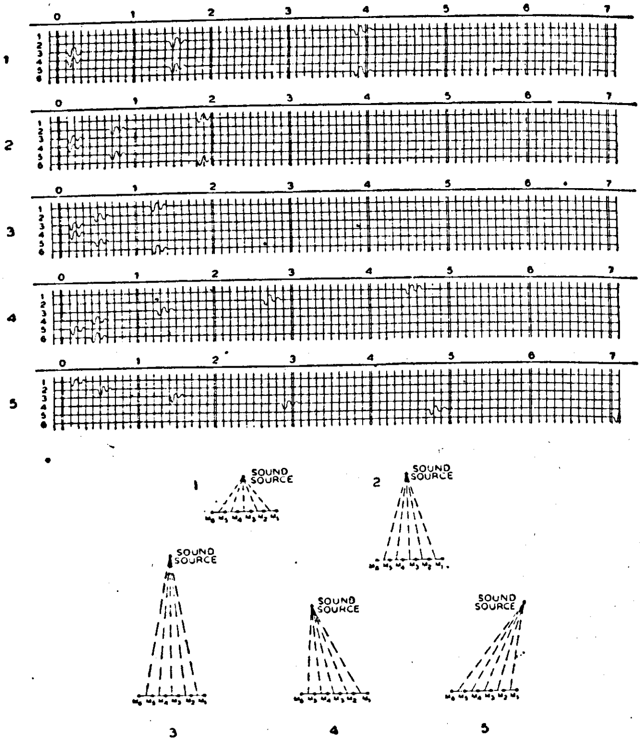


Figure 43. Typical oscillogram patterns (not actual records), straight base; locations of sound sources.

(2) When informed by the outpost observer of the approximate location of the sound source, the oscillogram reader visualizes the pattern that should be obtained. This frequently enables him to pick out the correct pattern although there are other patterns present on the oscillogram.

(3) Patterns for a curved base, shown in figure 44, are generally shorter than for a straight base, making it easier for the oscillogram reader to perceive the entire pattern at a glance, and to visualize the curve connecting the initial breaks. At ranges beyond the center of curvature of the

base, the pattern becomes concave to the left. Such a pattern is not possible for a straight base.

d. Ballistic waves. A projectile passing through the air at a velocity greater than the velocity of sound generates a sound known as a ballistic wave. This sound may easily be mistaken for the muzzle wave of a gun or other explosion. To the ear, it is often louder and sharper than that of the gun firing the projectile. It is heard only in a limited zone in front of the gun. It is not heard at considerable distances from the trajectory. One ballistic wave may be formed by the projectile on the ascending branch of the trajectory, and still another on the descending branch. Breaks produced on oscillograms by ballistic waves should not be mistaken for breaks produced by guns or bursting

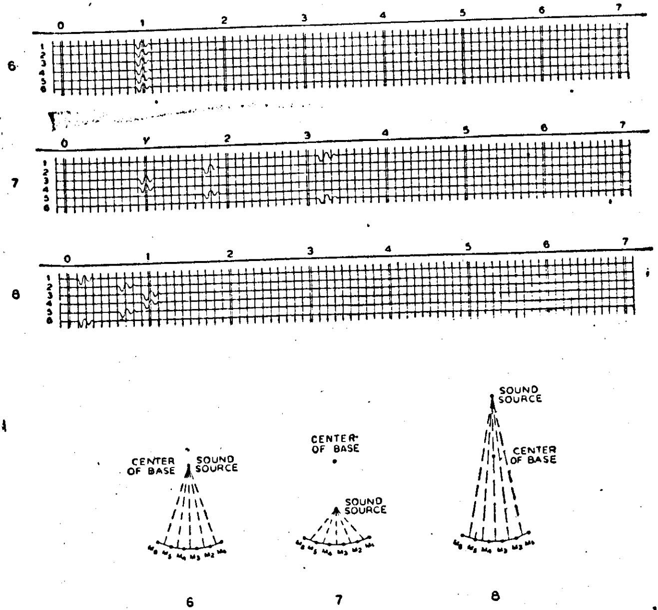


Figure 44. Typical oscillogram patterns (not actual records), curved base; locations of sound sources.

shells. Sound plotting methods assume that the sound originates at a fixed source. This is not the case for a ballistic wave. The ballistic wave striking one microphone may originate at one point on the trajectory, while that striking another microphone may have originated at another point. If an attempt is made to plot the sound source by the usual methods, the rays of the plot may be widely dispersed or they may converge to a reasonably small polygon of error. The resulting plot will be misleading, since the sound originates in a moving source on the trajectory and does not give the location of the gun. The sequence of arrival of the ballistic wave, sound of the shell burst, and gun wave at any one point depends upon a number of factors. (See fig. 79 and par. 104.)

e. Characteristic breaks. (1) *General.* As the air enters the microphone the trace moves downward, and as the air is expelled, it moves upward. Distinction between the wave shapes of a ballistic wave and of a gun wave, and estimation of gun caliber from the trace of an oscillogram, is dependent in part upon the fidelity with which the trace follows sound pressure variations at the microphone.

(2) *Ballistic waves.* Recording equipment which is sufficiently sensitive to the higher frequencies may record a ballistic wave, as shown by the first break in the third trace in figure 45, which can readily be distinguished from a gun wave. Equipment less sensitive to higher frequencies may record the same sound, as shown in the first break in the sixth trace in figure 45, in which case the trace may be mistaken for that of a gun wave. Experience with a particular design of equipment will determine into which class it falls. The relative amplitudes of recorded gun and ballistic waves do not agree with their relative loudness as heard by an observer and may be misleading to an oscillogram reader. A ballistic wave may sound much louder

than a gun wave, yet be recorded on the oscillogram with lower amplitude.

(3) *Caliber determination.* The period (fig. 40) of a gun wave is a function of the caliber of the gun. A measurement of the recorded period is an aid in estimating the caliber. Only smooth, typical gun waves with no obvious distortion should be used for this purpose. Results will be reasonably accurate *only* if the recording equipment is capable of following faithfully the sound pressure variations (note breaks in fig. 45). The recorded period will not be the same for all guns of the same caliber, but will vary with the design characteristics of the gun, such as its

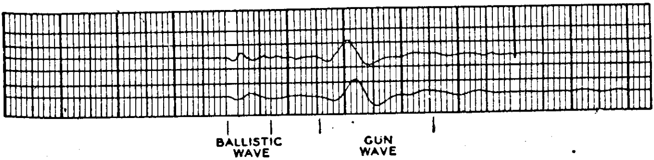


Figure 45. Ballistic and gun waves; upper record taken with equipment sensitive to high frequencies; lower record, of same sound, taken with equipment not sensitive to high frequencies.

tube length and powder charge, and with the weather and the range to the gun from the sound base. Data should be accumulated for modern guns likely to be encountered in combat. Specific weapons cannot be identified positively by this method unless there are other indications as to weapon type or unless only a few types are in use on a given front. However, guns can be classified as light, medium, or heavy.

83. THEORY OF SOUND PLOTTING. a. Propagation of sound. The discharge of a gun or burst of a shell causes a pressure disturbance in the air. This disturbance travels outward from the source in all directions at an approximately uniform speed. The sound wave travels upward as well as along the earth's surface. It may be visualized as a

constantly expanding hemisphere, with its center at the point of the origin of the sound. If there is no wind, and the entire mass of air has a uniform temperature of 50° Fahrenheit and uniform relative humidity of 50 percent, the velocity of the advancing wave front is 369.2 yards per second. These are the assumed standard conditions used in sound ranging.

b. Application of theory of hyperbola. If it is assumed that the gun and all microphones are in the same

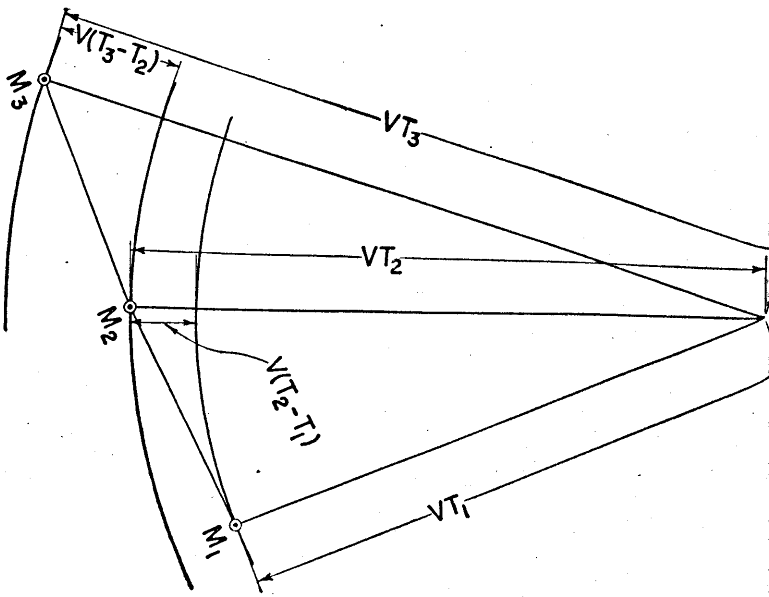


Figure 46. Distance and time relations for sound source.

plane and the oscillogram readings for two adjacent microphones are T_1 and T_2 (fig. 46), then the time difference $(T_2 - T_1)$, multiplied by the velocity of sound in air, V, equals the difference in distances traveled by the sound from the source to each of the two microphones, $V(T_2 -$

T_1). Since by definition a hyperbola is the locus of all points the difference of whose distances from two fixed points is constant, the sound source lies on a hyperbola whose foci (the two fixed points) are the two adjacent microphones, M_1 and M_2, and whose constant difference in distance is

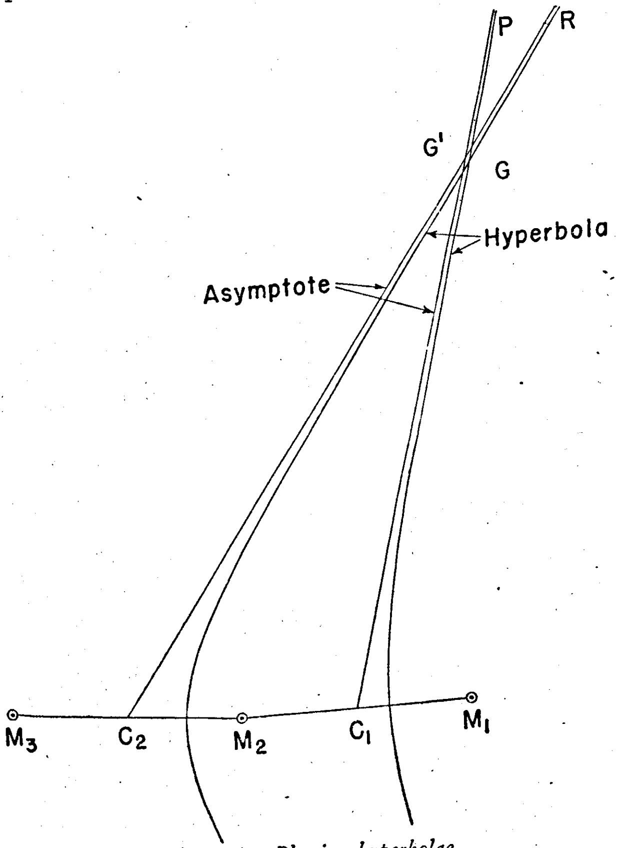


Figure 47. Plotting hyperbolae.

$V(T_2 - T_1)$. A hyperbola constructed on the base M_1M_2 for the difference $V(T_2 - T_1)$ would pass through the

sound source. A hyperbola constructed on M_2M_3 for $V(T_3 - T_2)$ would also pass through the sound source. (See fig. 47.) The intersection of the hyperbolae constructed for all pairs of adjacent microphones is the location of the sound source. The physical construction of a hyperbola for each time difference from each pair of adjacent microphones is impractical in sound ranging. Associated with each hyperbola is its asymptote, a straight line passing through the point (C_1) midway between the foci (M_1 and M_2) and tangent to the hyperbola at infinity. At ranges normally encountered in sound ranging, the hyperbola and its asymptote are only a few yards apart (G and G_1), introducing only a very small or negligible error. The construction of the asymptote may be simply and rapidly performed for each time difference between adjacent microphones.

c. Asymptotic plotting (fig. 48). (1) *Theory.* Let M_1 and M_2 represent two microphones, and C_1 the midpoint between them. OC_1 is constructed perpendicular to the sub-base. A plane wave front (from a source at an infinite distance on the prolongation of the line C_1B) which arrives at M_1 at time T_1 is represented by the straight line AM_1, perpendicular to BC_1. Time t later, the sound wave reaches M_2, having traveled the distance AM_2. The front of the wave remains perpendicular to BC_1, parallel to AM_1. In the right triangle AM_2M_1 =

$$AM_2 = Vt$$

$M_2M_1 = Vs$ where s = length of sub-base in sound seconds.

$$\frac{AM_2}{M_2M_1} = \frac{Vt}{Vs} = \frac{t}{s} = \sin \theta.$$

OC_1 is perpendicular to M_2M_1 and BC_1 is perpendicular to AM_1. Therefore, angle OC_1B is equal to θ, and for a sound source with a plane wave front,

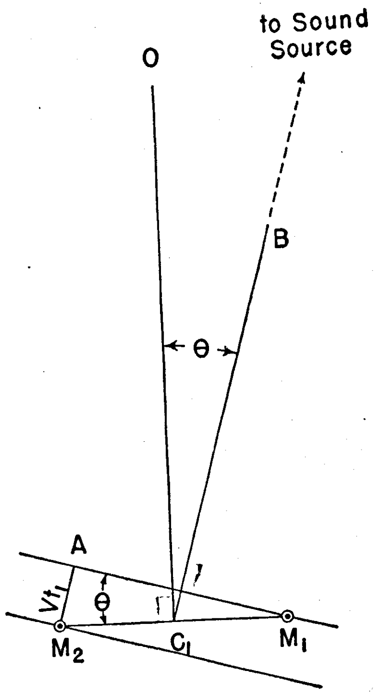


Figure 48. Direction of asymptote.

$$\sin \theta = \frac{t}{s}$$

in which t = the time interval, in seconds, between the sound arrivals at M_1 and M_2; s = the length of the sub-base, M_1M_2, is sound seconds; and θ = the angle between the perpendicular bisector of the sub-base and a line from the midpoint of the sub-base toward the source of sound.

(2) *Application* (fig. 49). M_1, M_2, M_3, M_4, and M_5 are the microphones of a sound base. The lengths of sub-bases are respectively s_1, s_2, s_3, and s_4. Midpoints of sub-bases are C_1, C_2, C_3, and C_4, and the perpendicular bisectors, or reference lines, are O_1C_1, O_2C_2, O_3C_3, and O_4C_4.

Weather conditions are standard. The times of arrival for a sound wave are T_1, T_2, T_3, T_4, and T_5. Time intervals are computed as follows:

$$t_1 = T_2 - T_1$$

$$t_2 = T_3 - T_2$$

$$t_3 = T_4 - T_3$$

$$t_4 = T_5 - T_4$$

For each sub-base, an angle θ is computed from the relation $\sin\theta = \frac{t}{s}$. Thus, θ_1 is the angle whose sine is $\frac{t_1}{s_1}\theta$. Each θ angle has the same sign as the corresponding t. A negative θ angle is plotted to the left of the proper reference line, and a positive θ angle to the right. In the example, t_1 is negative. θ is plotted to the left of O_1C_1 at C_1. For every other sub-base, a corresponding angle θ is computed and plotted. The intersection of the rays at G' is the approximate location of the sound source. If all sub-bases are the same length, θ varies with t only, and θ may be laid off with a scale or protractor graduated in terms of the corresponding time interval t.

(3) *Curvature correction.* The location G' is approximate because the relation $\sin\theta = \frac{t}{s}$ is applicable only when the incoming wave front is plane. For a spherical wave front, from a source at a finite distance (fig. 46), the sound source lies on the intersection of the hyperbolae instead of the asymptotes. (See fig. 47.) The correction required to move the approximate location G' to the true location G is the *curvature correction* or *asymptote correction.* A correction is applied separately to each angle θ, and *always increases* its numerical value. Let M_1 and M_2 (fig. 50) represent two microphones, C the midpoint between them,

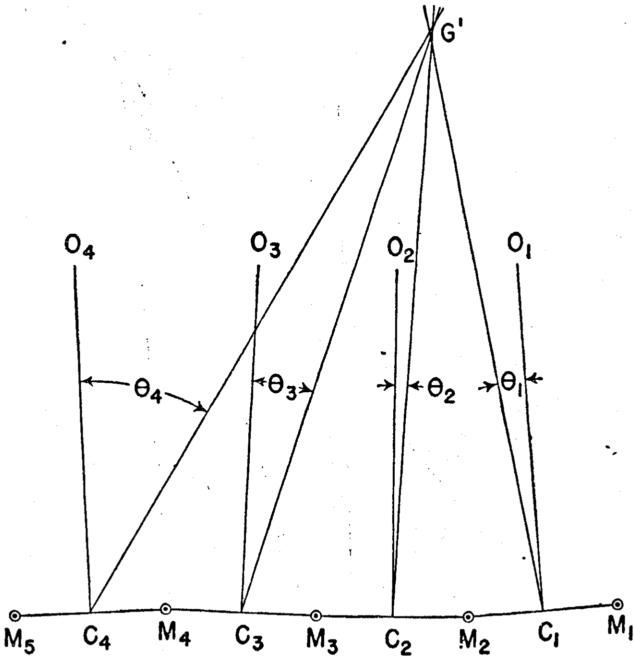


Figure 49. Plotting asymptotes.

and OC the perpendicular bisector of the sub-base. G is a sound source, t the observed time interval between arrivals of the sound at M_1 and M_2 under standard weather conditions, and V is the velocity of sound.

Let distance $GM_1 = a$, $GM_2 = b$, $CG = r$, and $M_1M_2 = Vs$.

Then $M_2C = CM_1 = \frac{Vs}{2}$, and $b - a = Vt$.

Construct CG' at an angle θ with OC. CG' is the asymptote of the hyperbola GH through the sound source G.

Instead of drawing a ray CG_1 at an angle θ from OC,

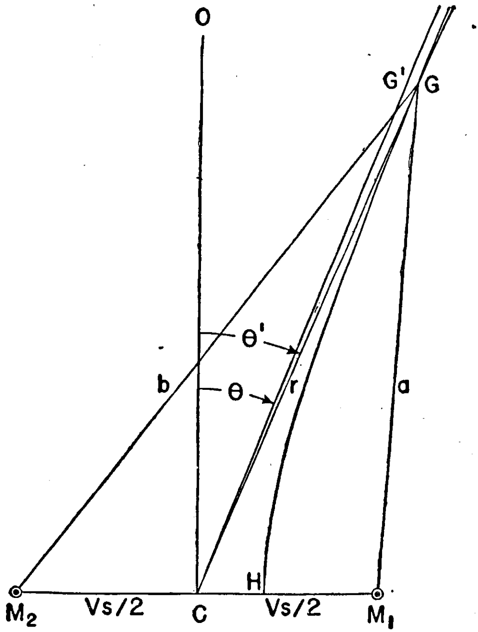


Figure 50. Curvature correction.

such that $\sin \theta = \frac{t}{s}$, ray CG is drawn at an angle θ', such that $\frac{t''}{s} = \sin \theta'$. To accomplish this, it is necessary to determine the time interval correction Δt that must be added to the actual interval t to obtain the corrected value t'', as follows:

$$t'' = t + \Delta t; \text{ or } \Delta t = t'' - t$$

$$\sin \theta' = \frac{t''}{s} = \frac{Vt''}{Vs}, \text{ or } Vt'' = Vs \sin \theta'$$

and so
$$\frac{t''}{t} = \frac{Vt''}{Vt} = \frac{Vs \sin \theta'}{b-a}$$

From the triangles GCM_1 and GCM_2, by the law of cosines:

$$a^2 = r^2 + \frac{V^2s^2}{4} - rVs \cos GCM_1$$

$$= r^2 + \frac{V^2s^2}{4} - rVs \sin \theta' \qquad (1)$$

and

$$b^2 = r^2 + \frac{V^2s^2}{4} - rVs \cos GCM_2$$

$$= r^2 + \frac{V^2s^2}{4} + rVs \sin \theta' \qquad (2)$$

Adding (1) and (2):

$$a^2 + b^2 = 2r^2 + \frac{V^2s^2}{2}$$

Subtracting (1) from (2):

$$b^2 - a^2 = 2rVs \sin \theta'$$

$$(b+a)(b-a) = 2rVs \sin \theta'$$

$$\frac{b+a}{2r} = \frac{Vs \sin \theta'}{b-a} = \frac{Vt''}{Vt} = \frac{t''}{t}$$

Squaring:

$$\frac{t''^2}{t^2} = \frac{(b+a)^2}{4r^2} = \frac{b^2 + 2ab + a^2}{4r^2} = \frac{2b^2 - b^2 + 2a^2 - a^2 + 2ab}{4r^2}$$

$$= \frac{2(b^2+a^2) - (b-a)^2}{4r^2}$$

$$= \frac{4r^2 + V^2s^2 - V^2t^2}{4r^2}$$

$$= 1 + \frac{V^2s^2 - V^2t^2}{4r^2}$$

Therefore:

$$\frac{t''}{t} = \sqrt{1 + \frac{V^2s^2 - V^2t^2}{4r^2}}$$

and
$$\Delta t = t'' - t = t\sqrt{1 + \frac{V^2s^2 - V^2t^2}{4r^2}} - t$$

or
$$\Delta t = t\left(\sqrt{1 + \frac{V^2s^2 - V^2t^2}{4r^2}} - 1\right) \qquad (3)$$

When the range r from the midpoint to the sound source is large compared to the length of the sub-base, this is approximately

$$\Delta t = t\left(\frac{V^2s^2 - V^2t^2}{8r^2}\right) = \frac{tV^2(s^2 - t^2)}{8r^2} \qquad (4)$$

In practice, the curvature correction for each sub-base is found by use of a chart which solves equation (3) or (4) above, after an approximate value for r has been determined.

(4) *Rough plot.* In order to determine r, a *rough plot* is made from the time intervals as determined directly from the oscillogram, with no corrections. This is sufficiently accurate, since the curvature correction is normally very small and is not changed appreciably by small errors in r. The approximate range, r, is scaled from each midpoint to the location obtained by the rough plot. These ranges are used in determining the curvature corrections for the corresponding sub-bases.

d. Weather corrections. Methods described above assume standard weather conditions in which the velocity of sound is 369.2 yards per second, and uniform in all directions. Standard conditions seldom, if ever, exist. When it is desired to correct sound plots for weather effects, time intervals are measured under existing conditions, corrections are applied to them to determine the intervals that would be recorded under standard conditions, and rays are plotted using the corrected intervals.

(1) *Wind.* The effect of a wind is to displace the entire expanding sound wave without distorting it, provided the entire volume of air involved moves at the same speed and in the same direction.

(*a*) *Theory* (fig. 51). M_1 and M_2 are two microphones. M_1M_2 is s sound seconds, or $M_1M_2 = Vs$. A sound source

is located at G. Weather conditions are standard except that a *uniform* wind of velocity w is blowing in the direction indicated by the arrow.

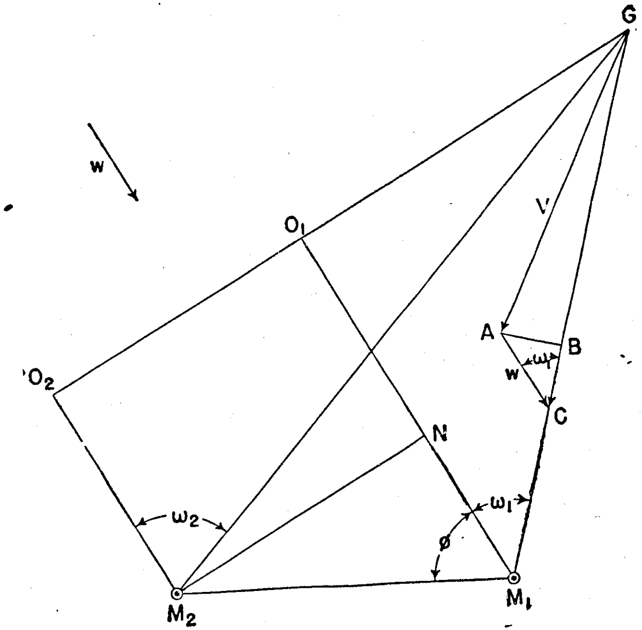


Figure 51. Wind correction.

Under the existing conditions, T_1' and T_2' are the times required for sound to travel from G to M_1 and to M_2, respectively, and the time interval is $t' = T_2' - T_1'$. Under standard conditions, the corresponding times of arrival would be T_2 and T_1, and the time interval $t = T_2 - T_1$. To obtain t, a correction Δt is added to the actual time interval t', such that

$$t = t' + \Delta t \text{ or } \Delta t = t - t'$$

O_1M_1 and O_2M_2 are constructed parallel to the direction of the wind, and GO_2 and NM_2 are perpendicular to

it. The angles between the wind direction and GM_1 and GM_2 are ω and ω_2, respectively. ϕ is the angle between the wind direction and sub-base M_1M_2.

Sound from G is propagated in all directions at a velocity V. That part of the sound wave reaching M_1 is not propagated in the direction GM_1, but in some other direction, such that the resultant of that velocity and the wind w is in the direction GM_1. In the velocity vector diagram superimposed on figure 51, the velocity of propagation V is added to w, producing a resultant along GM_1.

In the right triangle ABC

$$AB = w \sin \omega_1$$

$$BC = w \cos \omega_1$$

In the right triangle ABG

$$V^2 = AB^2 + BG^2$$

Therefore:

$$BG^2 = V^2 - AB^2 = V^2 - w^2 \sin^2 \omega_1$$

and

$$BG = \sqrt{V^2 - w^2 \sin^2 \omega_1}$$

The resultant of V and w is then

$$GC = BG + BC = \sqrt{V^2 - w^2 \sin^2 \omega_1} + \omega \cos \omega_1$$

In any practical case, AB is very small compared to V, so that BG, or $\sqrt{V^2 - w^2 \sin^2 \omega_1}$, is very nearly equal to V. Then the resultant velocity of sound along GM_1 is $V + w \cos \omega_1$. Similarly the resultant along GM_2 is $V + w \cos \omega_2$. Thus the times required for sound to travel from G to M_1 and M_2 are:

$$T_1' = \frac{GM_1}{V + w \cos \omega_1}$$

and $$T_2' = \frac{GM_2}{V + w \cos \omega_2}$$

The time interval is

$$t'=T_2'-T_1'=\frac{GM_2}{V+w\cos\omega_2}-\frac{GM_1}{V+w\cos\omega_1}$$

In the absence of wind:

$$t=T_2-T_1=\frac{GM_2}{V}-\frac{GM_1}{V}$$

Then, since the wind correction $\Delta t=t-t'$

$$\Delta t=\frac{GM_2}{V}-\frac{GM_1}{V}-\frac{GM_2}{V+w\cos\omega_2}+\frac{GM_1}{V+w\cos\omega_1}$$

$$=GM_2\left(\frac{1}{V}-\frac{1}{V+w\cos\omega_2}\right)-GM_1\left(\frac{1}{V}-\frac{1}{V+w\cos\omega_1}\right)$$

$$=GM_2\left(\frac{w\cos\omega_2}{V^2+V\,w\cos\omega_2}\right)-GM_1\left(\frac{w\cos\omega_1}{V^2+V\,w\cos\omega_1}\right)$$

But $\cos\omega_2=\frac{O_2M_2}{GM_2}$ and $\cos\omega_1=\frac{O_1M_1}{GM_1}$

So $\Delta t=\frac{O_2M_2w}{V^2+V\,w\cos\omega_2}-\frac{O_1M_1w}{V^2+V\,w\cos\omega_1}$

Since $V\,w\cos\omega_2$ and $V\,w\cos\omega_1$ are both small compared to V^2, this is very nearly:

$$\Delta t=\frac{O_2M_2w}{V^2}-\frac{O_1M_1w}{V^2}$$

$$=(O_2M_2-O_1M_1)\frac{w}{V^2}=(-NM_1)\,\frac{w}{V^2}$$

$$=-M_1M_2\cos\phi\,\frac{w}{V^2}=-V s\cos\phi\,\frac{w}{V^2}$$

$$\Delta t=-\frac{w\,s\cos\phi}{V} \tag{1}$$

Δt is added algebraically to the measured time interval to determine the corresponding time interval under standard conditions. It is independent of the position of the sound source, and for a given sub-base it changes only with the direction and speed of the wind.

(*b*) *Application.* This equation is solved in practice by use of the wind corrector or chart (par. 84d), with data

reported by the metro section. (See par. 27.) The sign of the wind correction is always such that it results in moving the plotted *ray* into the wind. In figure 52, M_1M_2 is a sub-base and OC is the perpendicular bisector. If the wind is from the right of the sub-base, as shown by the arrows to the right of OC, the sign of the wind correction is plus. If it is from the left, the sign is minus. The equation $\Delta t = \frac{ws \cos \phi}{V}$ indicates the wind correction to be zero for a wind perpendicular to the sub-base. This is correct *for the assumed condition of a uniform wind.* (Figure

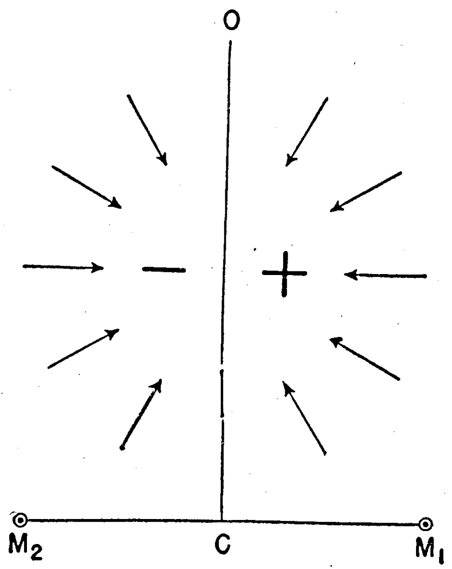


Figure 52. Sign of the wind correction.

53(a) illustrates the propagation of a sound wave from G under standard conditions. Each of the concentric circles shows the position of the advancing front of the sound wave at the indicated time in seconds after its origin. The

time of arrival at each microphone can be measured, and the time intervals computed. Figure 53(b) illustrates the propagation of the wave under conditions which are the same except that there is a uniform wind, perpendicular to the sound base. This wind carries the entire sound wave with it, without distortion. One second after the origin of the sound, the center of the wave is displaced downwind by the distance the wind has moved in 1 second, and the 1-second circle is drawn around this point. Each succeeding circle is displaced in the same way. The times of arrival at each microphone and the time intervals are determined as before. The times of arrival are changed from those under standard conditions, but the *time intervals* are the same. Since the wind has not changed the time intervals, no correction is required. The apparent sound source, obtained by plotting time intervals uncorrected for wind, does not necessarily lie directly downwind from the true sound source. The discrepancy is greatest for a flank wind and for a sound source well off the perpendicular bisector of the base. It is incorrect to plot the apparent sound source, and assume that the true sound source lies directly upwind from it. The equation in (*a*) above, is based on the assumption of a uniform wind. A uniform wind seldom if ever exists and as a result this equation frequently fails to compensate accurately for the effects of the wind. The effects of a non-uniform wind cannot be duplicated by *any* uniform wind and exact results cannot be obtained by measuring the *nonuniform* conditions and substituting in their place an "equivalent" or "effective" *uniform* wind.

(*c*) *Determining wind correction by registration.* The wind correction may be determined by registration on a point of known position (in the target area) relative to the sound base. The accuracy of the correction determined by this method is dependent upon the accuracy with which the registration point is located with respect to the base and

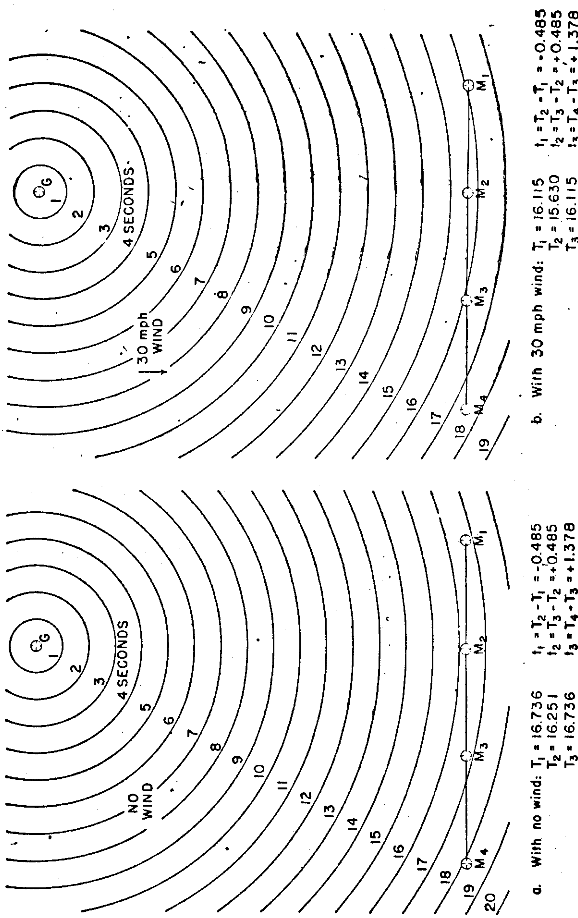


Figure 53. Effect of range wind.

upon uniformity of meteorological conditions. For any one sound source and any one pair of microphones, let

t = time interval under standard conditions,

t' = time interval under existing conditions,

Δt_o = curvature correction

$\Delta t_t =$ temperature correction

$\Delta t_w =$ wind correction

The registration point is plotted on the sound plotting chart. The time interval that must be plotted to obtain a ray through the sound source is t'' and may be scaled from the plotting board. t' is determined from the oscillogram. Then:

$$t'' = t + \Delta t_c$$

and

$$t = t' + \Delta t_w + \Delta t_t$$

Solving for the wind correction:

$$\Delta t_w = t'' - (t' + \Delta t_t + \Delta t_c)$$

The wind correction is then the recorded time interval, corrected for curvature and temperature, subtracted from t'' as scaled from the plotting board. The wind correction is determined in the above manner for each sub-base. The registration point should be located near the center of the target area. Such a wind correction is valid as long as weather conditions remain unchanged.

(2) *Density.* The velocity of sound in the air is proportional to the quantity $\sqrt{\gamma \frac{p}{d}}$ in which γ is a physical constant of the gases of the air, p is the air pressure, and d is the air density. For any change in pressure, at constant temperature and humidity, the ratio $\frac{p}{d}$ remains constant and therefore produces no effect on the velocity of sound. The complete effect of any changes in density are obtained by applying corrections for temperature and humidity.

(3) *Temperature.* The density of air decreases as the temperature increases, resulting in an increase in the velocity of sound. If the temperature is higher than the standard value of 50° F., the time intervals read from the oscillogram must be increased numerically to obtain the equivalent

time intervals at standard temperature, and decreased numerically if the air temperature is below 50° F. The velocity of sound in air is proportional to the square root of the absolute temperature. If V is the velocity at 50° F. and V_x the velocity at any Fahrenheit temperature X, then

$$\frac{V_x}{V}=\sqrt{\frac{460+X}{460+50}}=\sqrt{\frac{510+X-50}{510}}=\sqrt{1+\frac{(x-50)}{510}}$$

The time intervals vary inversely as the velocity of sound. If t is the time interval under standard conditions, t_x the time interval at temperature X, and Δt the time interval correction that must be added to t_x to obtain t, then:

$$\frac{t}{t_x}=\frac{V_x}{V}=\sqrt{1+\frac{X-50}{510}}$$

$$t=t_x\sqrt{1+\frac{X-50}{510}}$$

Therefore:

$$\Delta t=t-t_x=t_x\sqrt{1+\frac{(x-50)}{510}}-t_x$$

$$\Delta t=t_x\left(\sqrt{1+\frac{X-50}{510}}-1\right)$$

The correction is determined graphically by use of the temperature correction chart. An approximate correction may be obtained by adding one-thousandth of the recorded time interval to t_x for each degree of temperature above 50° F., or subtracting for each degree below 50° F. This correction assumes uniform conditions throughout the asmosphere.

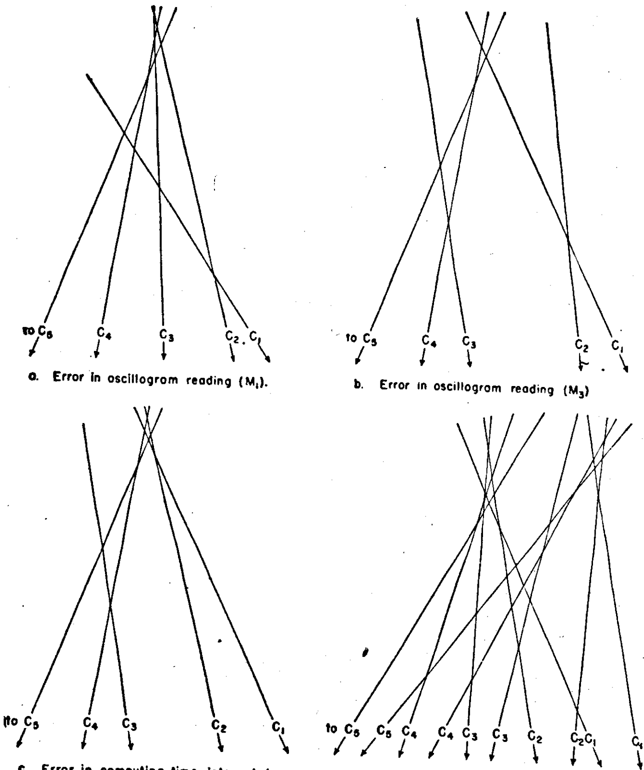
(4) *Humidity.* Fifty percent relative humidity at 100° F. represents more water vapor in the air than 50 percent relative humidity at 50° F. The additional water vapor affects the velocity of sound in addition to the effect due

to the increased temperature. The fact that the *relative* humidity is the same at the higher temperature as for standard weather conditions does not preclude the necessity for a humidity correction. The addition of water vapor to the air decreases the air density compared to the density of dry air at the same pressure and temperature, as the weight of the water vapor is less than that of the gases it displaces. Decrease in density results in an increase in the velocity of sound. At low temperatures, the effect of humidity on the velocity of sound is negligible. When both the temperature and relative humidity are high, the effect may become appreciable. This may be conveniently compensated for by combining the temperature and humidity to obtain a *virtual temperature.* The metro section determines the virtual temperature and reports it to the sound ranging section as the effective temperature.

e. Polygon of error. With accurate survey and complete curvature and weather corrections, a *point plot* (all rays of the sound plot intersecting at the same point) is seldom obtained, principally because exact weather corrections can not be made. The polygon bounded by the intersecting rays is termed the *polygon of error.*

(1) *Interpretation.* A point plot or a small polygon of error gives the impression of being an accurate location, but is not necessarily so. Survey errors or weather effects can displace the entire plot without appreciably enlarging the polygon of error. Other factors as well as appearance should be considered (par. 93c) before a point plot is accepted as an accurate location. The application of weather corrections frequently enlarges the polygon of error but improves its position. A large polygon of error, particularly with one or two rays widely divergent from the rest, may indicate an error due to a terrain obstruction (large building or hill) or an error in oscillogram reading, computed time intervals,

plotting, or survey. Certain of these errors produce characteristic plots which may indicate the source of error. If the microphone is on the flank, only the ray from the midpoint on that flank will be in error. If the microphone is an in-



a. Error in oscillogram reading (M_1).

b. Error in oscillogram reading (M_3)

c. Error in computing time interval (ray from C_3).

d. Two plots; error in survey (sub-base M_3 - M_4 too short).

Figure 54. Effects of common errors on appearance of plots.

terior one, the two rays from the midpoints on either side will be in error in opposite directions. Plots similar to those described above result from an error in reading a break on

the oscillogram, where only one ray is affected if the break on a flank microphone is read erroneously (fig. 54 (a)), while an error in reading the break on an interior microphone causes the two adjacent rays to be in error in opposite directions. (See fig. 54(b).) An error in plotting or computing time intervals affects only one ray. (See fig. 54(c).) An error in survey causes distortion of plots similar in shape for all sound sources. (See fig. 54(d).) Any radical change in the appearance of the polygon of error between successive plots in the same general area suggests the presence of errors or a large change in weather conditions. None of the above effects are evident in a plot of less than three rays. *Two-ray plots are not reliable.*

(2) *Evaluation of polygon of error.* The polygon of error must be evaluated to determine the probable location of the sound source. This is accomplished by inspection unless the polygon is very large or time is available for a more careful evaluation. When the polygon is not evaluated by inspection, either of the methods described below may be used. In each case a unit weight is given to the intersection of any two rays, which simplifies procedure but does not take into account relative strength of the intersection.

(*a*) *By computation.* If a grid has been placed on the sound plotting board, the coordinates of the intersection of each pair of rays is read. There are three such intersections in a three-ray plot, six in a four-ray plot, and ten in a five-ray plot. The *X* coordinates of all intersections are averaged to obtain the mean *X* coordinate, and the *Y* coordinates of all intersections are averaged to obtain the mean *Y* coordinate.

(*b*) *Graphical method.* A graphical method of locating the same point is illustrated in figure 55. The intersection may be considered in any sequence, without varying results, but an orderly sequence simplifies the procedure.

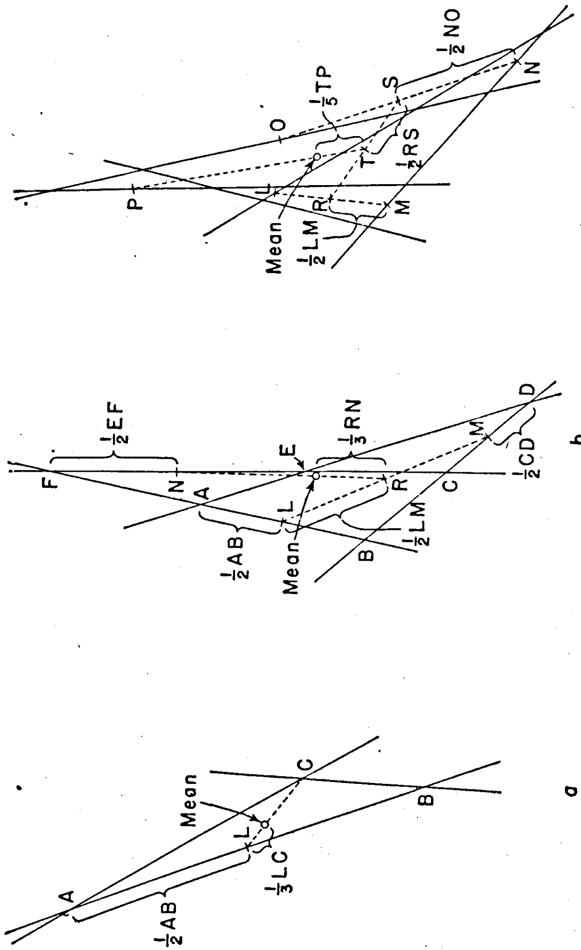


Figure 55. Graphical evaluation of polygon of error.

1. *Three-ray plot.* In figure 55(a), *A, B,* and *C* are the three intersections of a three-ray plot. *L* is the midpoint of *AB.* The mean of *A, B,* and *C* lies on the line *LC,* one-third of the distance *LC* from *L.*

2. *Four-ray plot.* In figure 55(b), *A, B, C, D, E,* and *F* are the six intersections of a four-ray plot. *L, M,* and *N* are the midpoints of *AB, CD,* and *EF,* respectively. The mean of *L, M,* and *N,* which is also the mean of the six intersections, is found in the same way as the mean for the three-ray plot.
3. *Five-ray plot.* The ten intersections are grouped into pairs (fig. 55(c)) and the midpoint of each pair is located, as at *L, M, N, O,* and *P.* The mean, *T,* for four of these midpoints is found by locating *R* midway between *L* and *M, S* midway between *N* and *O,* then *T* midway between *R* and *S.* The over-all mean for the plot lies on a line joining *T* and *P,* the midpoint of the fifth pair, one-fifth of the distance *TP* from *T.*

f. Relative locations. (1) *Theory.* When the internal survey is only approximate, where corrections are not applied, or when the chart location of the base is not accurately known, locations of sound sources are determined relative to other sound sources which have been plotted under identical weather conditions. In figure 56, the sound base has been surveyed by approximate methods. *A, BP,* and *C* are the true locations of the sound sources (which could not be plotted on the sound ranging chart because their positions are unknown). A sound from *A* is recorded and plotted without corrections. The plotted location at *A′* is displaced from the true location of *A* due to weather effects and survey inaccuracies. Similarly, the plots of recorded sounds from *BP* and *C* are at *BP′* and *C′*, respectively. Since *A, BP,* and *C* are in the same general area (within assumed standard transfer limits, FM 6–40), the factors which displaced *A′* from its correct position are approximately the

same as those which displaced *BP′* and *C′*, and it may be assumed that all have been displaced approximately the same distance and direction. If *BP* is a base point upon which artillery has registered and the approximate gun-target line is known, or if *BP* is the point of impact of a round fired at any known deflection and range, the shifts required to place fire on *A* or on *C* are measured from the sound plotting chart and reported as described in paragraph 93.

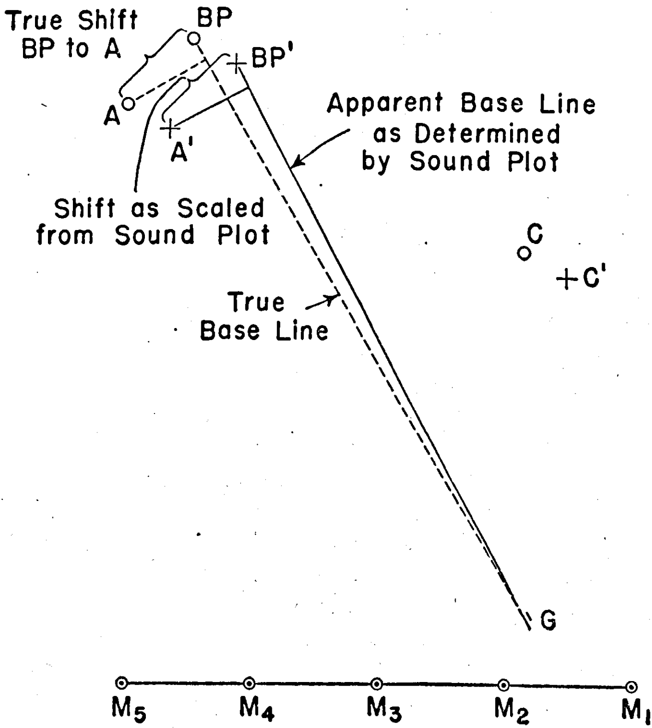


Figure 56. Relative locations.

(2) *Conditions required for accuracy.* Relative locations are accurate only if no appreciable change in weather condi-

tions has occurred during the period in which sounds from the various sources were recorded. The accuracy increases with improvement in survey, and increases as the distance between the two sound sources decreases. Thus, in figure 56, if C is too far from BP, the shift from BP' to C' as scaled from the plot may not be sufficiently accurate for effective transfer of fire. If adjusting rounds are fired at the estimated position of C, they may be sufficiently near C to permit an accurate sensing to be made. As rounds fall progressively nearer to C, the accuracy of deviations as measured from the sound plot is progressively improved. In the limiting case, however inaccurate the survey, when a round is placed on C, no change having occurred in weather conditions, the oscillogram for the original plot at C' should be identical with the oscillogram from the round placed on C and the two plots should coincide.

(3) *When employed.* Relative locations are used only when survey is performed by approximate methods. Weather and curvative corrections are normally omitted when relative locations only are made. In sound ranging adjustments, uncorrected plots are made to speed up the adjustment. If initial data have been determined from corrected plots, the target must be replotted without corrections. Relative locations can not be reported to the firing units in useful form until sound plots have been made on shell bursts fired by these units..

(4) *Adjusting reference lines.* When relative locations are plotted, the reference lines may be adjusted to reduce the size of the polygon of error and to facilitate evaluation of the polygons by inspection. Adjustment of reference lines is not a correction for weather effects or inaccuracies of survey, nor does it move the position of the center of the plot appreciably. It must be verified that polygons of error are consistently of the same approximate size and shape. A plot based on a single oscillogram, or on the

average time intervals from several oscillograms obtained from the same sound source, is selected. The center, P, (fig. 57) of the polygon of error is determined by inspection. The angle θ_1 which was originally plotted from reference line $O_1 C_1$ to obtain one ray of the plot, is now plotted in the reverse direction from PC_1 to locate a new reference line $O_1' C_1$. In the same way, $O_2 C_2$, $O_3 C_3$, etc. are adjusted. As a check, the original set of time intervals from the new reference lines are replotted and should produce a point plot at P. Plots of other sounds in the vicinity of P should also afford point plots or small polygons of error. If the polygon opens up due to a large shift or to changes in weather conditions, a readjustment is made. Transfer of fire from one plotted point to another may be made only when the same reference lines are used in plotting both points. If survey errors result in inaccuracies in certain elements of the sound base, it may be assumed that some rays of a plot are more accurate than others. In such cases, the position of point P, to be used as a basis for adjusting reference lines, is determined by proper weighting of the various rays. If M_1, M_2, and M_3 are accurately located, while M_4 and M_5 are not, P is the intersection of the rays from C_1 and C_2, in which case only reference lines $O_3 C_3$ and $O_4 C_4$ would be adjusted.

(5) *Forcing plots.* When the true or approximate location of a sound source in relation to the base is known, regardless of the accuracy of the internal survey of the base, the reference lines may be adjusted to obtain a point plot at the known location of the sound source.

84. COMPUTING CORRECTED TIME INTERVALS. a. General. Time intervals are computed from oscillogram readings as described in paragraph 82a. When survey is performed by accurate methods, curvature and weather corrections are applied (except for sound ranging adjust-

ments). FAS Form 4 is used in computing corrected time intervals as illustrated by the example in *e* below.

b. Temperature correction. A temperature correction chart, based on equation (1) of paragraph 83d(3), is shown in figure 144. This chart is entered with the uncor-

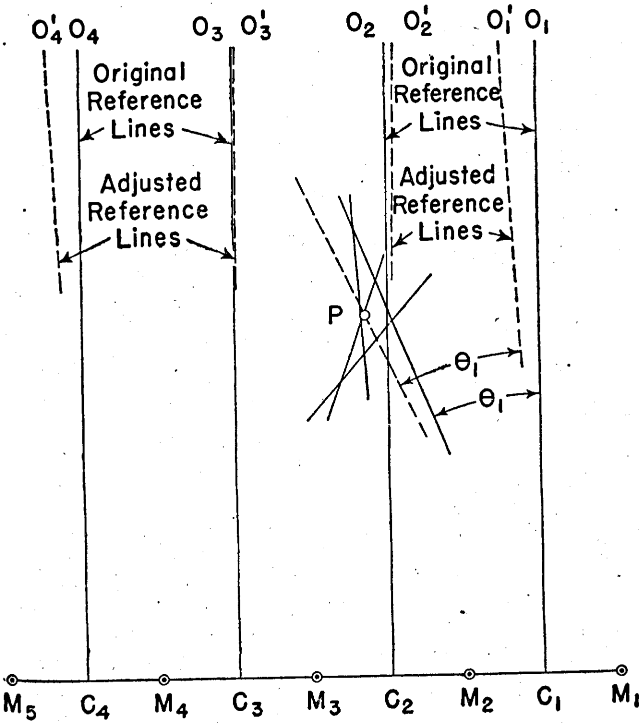


Figure 57. Adjusting reference lines.

rected time interval and with the temperature (either effective or virtual) as reported by the weather section. A temperature correction is obtained from the chart for each time interval.

c. Curvature correction. The approximate range to each midpoint is found to the nearest 100 yards from a rough plot. (See par. 83c(4).) This plot may be made on a separate board at a reduced scale without a grid. The curvature correction chart for the proper length sub-base is used. Charts for 2, 3, 4, 4½, 5, and 5½ second sub-bases are shown in figures 145, 147, 149, 151, 153, and 155, respectively. These charts are based on equation (3) of paragraph 83c(3). The chart of figure 157, which is based on equation (4) of paragraph 83c(3), is used for sub-bases of nonstandard lengths. A correction is determined from the chart for each time interval.

d. Wind correction. The wind correction may be determined by the use of the wind corrector M1 or wind charts, or by registration. The wind corrector and wind charts are based on equation (1) of paragraph 83d(1). Wind corrections for a straight regular base, except when determined by registration, are the same for all sub-bases. In other cases, a correction is determined for each sub-base. The same set of corrections is used for all sound sources and need not be redetermined until new weather data are obtained.

(1) *Wind corrector M1.* The wind arm of the wind corrector M1 (fig. 58) carries a strip with four scales engraved on it, one along each edge, front and back. The scales are graduated for 4, 4½, 5, and 5½ second sub-bases. The strip is attached to the wind arm so that the desired scale is along the edge passing through the pivot. The wind arm is set at the reported wind azimuth in degrees (on the outer azimuth scale) or mils (on the inner azimuth scale). The five sub-base markers are moved around the azimuth scales to mark the *back-azimuth* of each sub-base. Only one marker is required for a straight base. The central disk is rotated to line up the arrow on it with the marker for the

first sub-base. Opposite the value of wind velocity on the wind arm scale, the wind correction is read from the parallel lines on the central disk. The sign is indicated on the disk. Corrections for other sub-bases of different azimuths are found in the same manner.

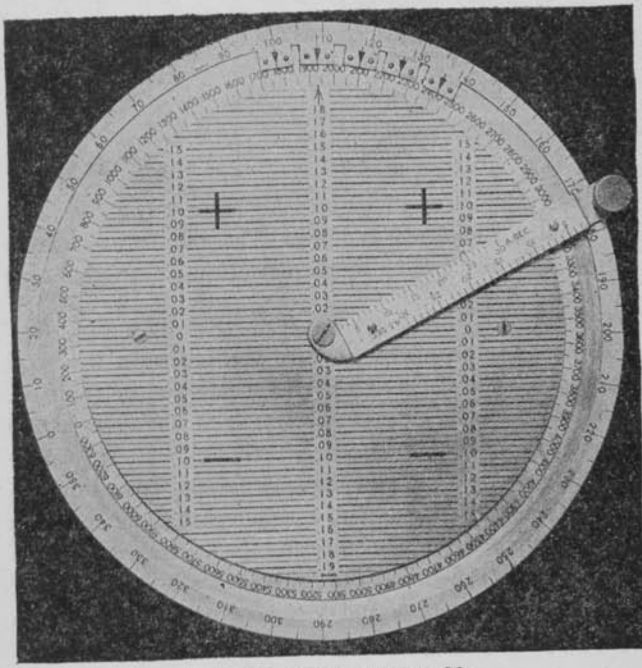


Figure 58. Wind corrector, M1.

(2) *Wind correction charts.* The wind corrections for standard sub-base lengths may be determined from the appropriate chart, figures 146, 148, 150, 152, 154, or 156. The chart of figure 158 permits the wind correction to be determined for nonstandard length of sub-bases.

e. Illustrative example. The effective temperature is 57° F., wind direction 900 mils, wind speed 11 miles per

hour. A six-microphone 4-second sound base has been installed, with an azimuth of 2°25′20″ (back-azimuth of 182°25′20″). The following oscillogram readings are obtained:

T_1: 2.887 seconds

T_2: 2.028 seconds

T_3: 1.398 seconds

T_4: 1.017 seconds

T_5: 0.897 seconds

T_6: 1.020 seconds

These values are entered on FAS Form 4 (fig. 59), and the form is completed as shown. The approximate ranges were determined from a rough plot of the uncorrected time intervals.

f. Mean intervals for several oscillograms. If several oscillograms are obtained for one enemy gun or from the guns of a closely grouped battery, it is not necessary to complete FAS Form 4 for each oscillogram. The corresponding uncorrected time intervals for the several oscillograms should be compared to ascertain that all agree within a few thousandths of a second, and then averaged to obtain a set of mean time intervals. Corrections are applied to the averaged time intervals and a corrected plot of the mean location is made.

85. METHODS OF PLOTTING. a. Regular base fan. A transparent fan (fig. 60) may be employed for plotting with any fixed length of sub-base. To prepare the board for plotting, the midpoints of the sub-bases are plotted near the lower edge of the board to the scale at which it is desired to plot sound locations. When plotting on a map or air photo, the scale of the map or photo is used. A segment of the reference line is drawn to fall under the time

SOUND PLOTTING RECORD

Base: Location 845 Type 4 Sec. Straight Azimuth 2° 25' 20" Date 9 May 1944

Oscillogram No. 54 Time 2132 Temperature 57 °F Wind: Direction 900 mils Speed 11 mph

Time Readings

Results to (−)		2.887	2.028	1.398	1.017	
	1 2.887	2 2.028	3 1.398	4 1.017	5 0.897	6 1.020
Results to (+)						0897

	1		2		3		4		5	
	+	−	+	−	+	−	+	−	+	−
Time Interval		0.859		0.630		0381		0.120	0.123	
Curvature Correction										
Temperature Corr.		0.006		0.005		0.003		0.001	0.001	
Wind Correction		0.040		0.040		0.040		0.040		0.040
Sub-Totals		0.905		0.675		0.424		0.161	0.124	
Subtract		0		0		0		0	0.040	
Corrected Time Interval		0.905		0.675		0.424		0.161	0.084	
Approximate Range										

Coordinates: X 68338 Y 95704 Accuracy 100 yards Caliber ______ File No. ______

Area Shelled ______ No. of Pieces ______ Time Reported ______ Conc. No. ______

FAS Form No. 4 F.A.S. Fort Sill, Okla. (6-19-44—18,900)—8003 387-384-A

Figure 59. Example—FAS Form 4.

scales of the fan for each sub-base. Each reference line is marked with a prominent arrowhead. A map pin is inserted at each midpoint. The fan is centered on the map pin at the first midpoint. The value of the first time interval t_1 is set on the time scale of the fan over the first reference line, and a ray drawn along the appropriate edge of the fan. If t_1 is positive, it is set on the upper time scale; if t_1 is negative, it is set on the lower time scale. Other time in-

tervals are plotted from their respective midpoints in the same manner. Small holes drilled through the fan constitute a template for plotting the locations of midpoints of a straight base at the scale for which the fan is designed. Similar holes below the time scales mark the corresponding positions for reference lines.

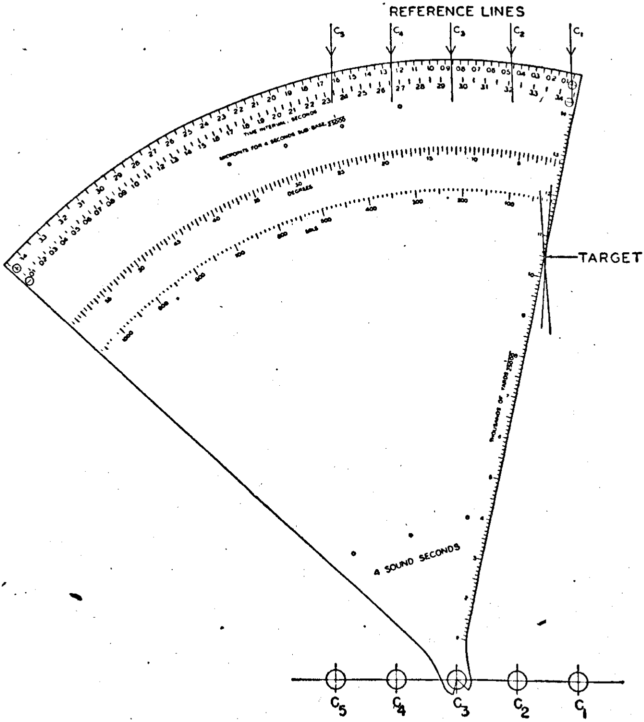


Figure 60. Regular base plotting fan.

b. Improvised plotting board. Time scales similar to those on the sound plotting fan may be drawn on the surface of the plotting board. (See fig. 61.) The positions of the midpoints are plotted and a separate scale drawn for each sub-base, the zero point of which is on the perpendicu-

lar bisector of the sub-base, positive values to the right and negative values to the left. All are constructed concentric about C_3. In plotting, a ray is drawn from each midpoint to the point on the time interval scale corresponding to the time interval for the corresponding sub-base. Each ray may be materialized by a thread or gut stretched across the board, attached to the midpoint, and affixed at the proper point on the time scale, usually by means of a small weight. Applications of this type plotting board are limited. A plotting board constructed for a standard curved base or for an irregular base can be used only for the particular base for which constructed. A plotting board constructed for a straight base may be used for other length sub-bases but the scale of plotting must be varied to correspond and a factor applied to each time interval. (See par. 86.) For example: a board designed for 1/50,000 plotting for 4-second sub-bases may be used for 1/25,000 plotting for 2-second sub-bases providing each time interval is multiplied by 2 to adapt it to the 4-second time scales. Reference lines cannot be adjusted on this type plotting board and the polygon of error must be reduced by application of a constant time interval correction for each sub-base.

c. Mechanical plotting board. The operation and care of the mechanical sound ranging plotting board is described in TM 9–2684. This board provides an accurate means of plotting. It can be used for any of the standard curved bases or for 4, 4½, 5, or 5½ second straight bases at a scale of 1/20,000. Plotting can also be performed for the same straight bases at a scale of 1/40,000. Other lengths of sub-base may be used if the scale of plotting is changed accordingly and the proper factor applied to each time interval. (See par. 86.)

d. Irregular base fan. (1) *General.* The irregular base fan is designed to plot for any length of sub-base. Figure

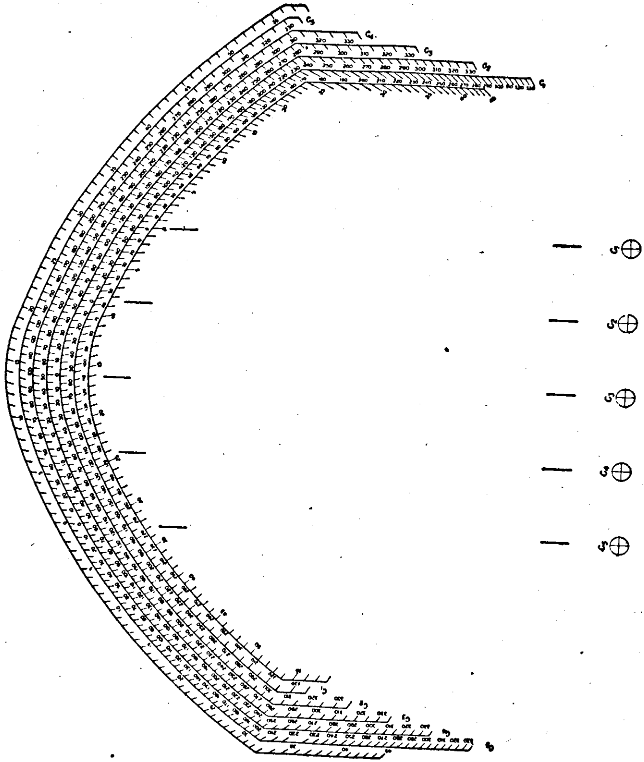


Figure 61. Improvised plotting board.

62 illustrates a fan with both irregular base scales and 2-second base time scales. In preparing the plotting board, the midpoints are plotted and a reference line is drawn for each sub-base. An index mark is constructed at right angles to each reference line, a sub-base length distant from the mid-point of the sub-base, as measured by the sub-base scale along the left edge of the fan. This scale is independent of the scale of the sound plot. The intersection of each reference line and the appropriate index is marked by a

prominent arrowhead. A map pin is inserted at each midpoint. The fan is used face up for positive time intervals, and face down for negative time intervals. The fan is centered on the map pin at each midpoint, in turn, and rotated until the index mark lies under the computed time

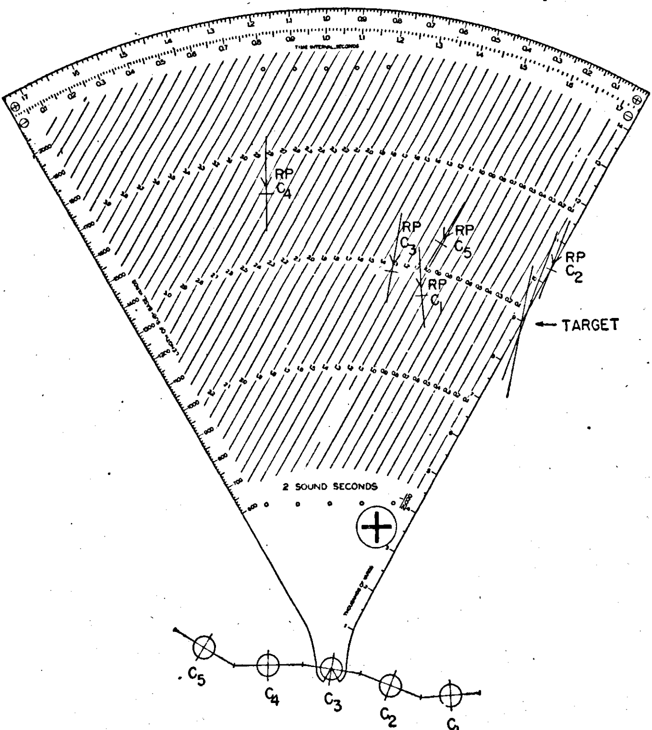


Figure 62. Irregular base plotting fan.

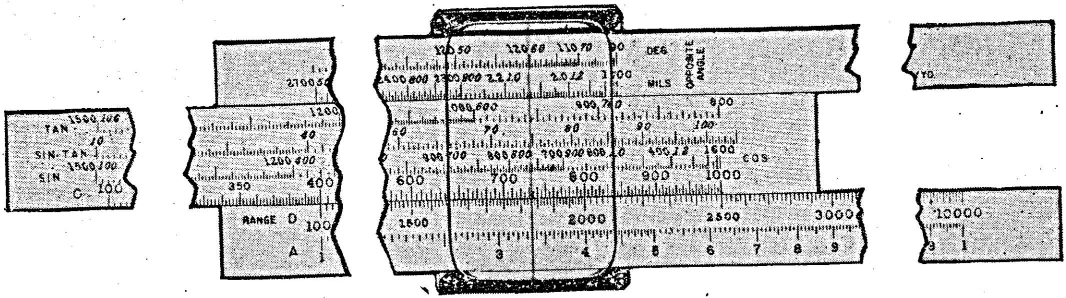
interval as read from the scale on the parallel time lines. A ray is then drawn along the edge of the fan which is parallel to the time lines.

(2) *Automatic temperature correction.* A temperature correction may be applied automatically to each ray by shift-

ing the position of the index marks. The length of each sub-base is multiplied by $369.2/V_x$, in which V_x is the velocity of sound at the existing effective air temperature. (See sec. XV, ch. 9.) The index marks are located on the basis of these modified sub-base lengths.

(3) *Adjusting reference lines.* To force a plot through a point *P*, when plotting with the irregular base fan, draw a ray from the first midpoint through *P*. Place a temporary index mark on this ray at the proper distance from the midpoint as measured by the sub-base scale. Reverse the sign of the measured time interval for the first sub-base, and draw a ray using this time interval and the temporary index mark. The second ray is the adjusted reference line. Place an index mark on the adjusted reference line and erase the ray through *P*. Repeat for each sub-base. As a check, use the adjusted reference line and the same set of time intervals with the original signs to verify a point plot at *P*.

e. Range-deflection fan. Plots for any type sound base may be made by solving the equation $t/s = \sin\theta$ to determine the angle θ corresponding to each recorded time interval, and plotting the angle with a range-deflection fan. The equation may be solved by the use of the military slide rule. The index of the C scale is set over the sub-base length in sound seconds on the D scale. (See fig. 63.) The hairline is set on the time interval on the D scale, and directly above this point the angle θ in mils is read from the SIN scale, if the time interval is *greater* than one-tenth of the sub-base length, or from the SIN-TAN scale if the time interval is *less* than one-tenth of the sub-base length. A temperature correction is applied automatically if the length of each sub-base in sound seconds is computed as the length in yards divided by V_x, the velocity of sound in yards



Example: s = 2.5 sound seconds (D scale)
t = 1.833 seconds (D scale)
θ = 838 m̸ (SIN scale)

Figure 63. Computing θ with the military slide rule.

per second at the existing effective air temperature. (See sec. XV, ch. 9.)

86. ADAPTING TIME SCALES AND CHARTS TO SUB-BASES OTHER THAN THAT FOR WHICH THEY WERE CONSTRUCTED. a. General. When it is desired to use a correction chart, or the time scale of a plotting fan or plotting board, for a sub-base length other than that for which they were designed, the procedure is as follows:

(1) *Time scales.* (*a*) Assume that a time interval t_a has been recorded on a sub-base s_a seconds long. Then

$$\frac{t_a}{s_a} = \sin \theta_a.$$

The only fan available has time scales for a sub-base of s_b seconds. But

$$\frac{t_a}{s_a} = \frac{\left(\frac{s_b}{s_a}\right) t_a}{s_b} = \sin \theta_a$$

where $\left(\frac{s_b}{s_a}\right) t_a$

is the time interval that must be laid off on the fan calibrated for a sub-base of b seconds, to obtain the angle θ_a.

(*b*) A 4-second fan may be used with a 2-second sub-base if each time interval is multiplied by 4/2, or 2, or with a 5-second sub-base if each time interval is multiplied by 4/5. The irregular base fan of figure 62 may be used for a 2,400-yard sub-base by locating the index mark 1,200 yards along the sub-base scale, and dividing the time intervals by 2. The midpoints of the sub-bases are plotted in their true positions as measured by the scale of the plot.

(2) *Temperature correction chart.* The temperature correction chart applies without modification for any length of sub-base.

(3) *Curvature correction chart.* A curvature correction chart designed for sub-base s_b may be used for any sub-

base s_a by *multiplying* both the range and the measured time interval by $\frac{s_b}{s_a}$ before entering the chart. The correction read from the chart is *divided* by the same factor. In the simple case where $\frac{s_b}{s_a}$ is 2, such as when a 4-second chart is used for a 2-second sub-base, the same result is obtained if each figure on the scales of the chart is divided by 2, converting it to a 2-second chart. The same method is used to adapt the irregular base curvature chart to cover wider ranges of sub-bases.

(4) *Wind correction.* The wind correction is directly proportional to the length of the sub-base. A wind corrector may be prepared for a sub-base s_b and the correction as read from the corrector multiplied by the factor $\frac{s_a}{s_b}$ to obtain the correction for a sub-base of s_a seconds. (Note that this factor is the reciprocal of that used in (1) above.)

b. Missing string plots. The missing string plot for a regular straight base is a special case of adapting both the time scale and the correction charts to a double length sub-base. Assume that on a five-microphone straight base an oscillogram possessed readable breaks for all microphones except M_2. The sub-bases used in making a plot would be M_1M_3, M_3M_4, and M_4M_5, the first of which is double the normal length. The following simplified procedure for plotting the ray for the double length sub-base produces the same results as obtained by following the procedures of a above:

(1) Determine the time interval for the double length sub-base, and divide it by 2. *All further reference below to time interval refers to this half value.*

(2) Apply curvature and weather corrections to the time

interval in the normal way, except that half the actual range is used in entering the curvature correction chart.

(3) Plot the corrected time interval using a time scale for a normal length sub-base, from the midpoint and reference line of the double length sub-base.

For a curved base, the above method is not exact, as the sub-base M_1M_3 is less than twice the normal value. When using the mechanical plotting board, the pivot of the plotting arm cannot be set exactly over the midpoint of sub-base M_1M_3. Errors introduced by these effects are small and will not affect the final locations materially.

c. Miniature base. A miniature base, in which all elements are a specified integer fraction (such as 1/10) of the corresponding elements of a standard base, is useful for training purposes. This is a special case where an integer factor may be applied to both the time scales and correction charts. The following simplified procedure is used: First, prepare the plotting board for plotting at 1/20,000 for a standard base. With a base 1/10 normal size, the plotting will be at a scale of 1/2,000. A 1.8-inch grid will correspond to 100 yards between grid lines. Then multiply the time intervals by the integer factor (in the example by 10). The resulting intervals are corrected and plotted as for standard length sub-bases. The approximate ranges, upon which the curvature corrections are based, are scaled from the rough plot with 1/20,000 scale; the proper factor is automatically applied to the ranges used in entering the chart. Polygons of error are somewhat larger than with a standard size base because of the enlarged scale of the plot.

87. PLOTTING WITH SOUND SOURCE TO REAR. a. Straight base. With a straight base, if a sound from the rear of the base is recorded and plotted in the normal manner, a false location is obtained to the front of the base.

The plot itself affords no indication of this error. Normally the reports of the outpost observers or the installation of an offset microphone will prevent such errors. In the event it is desired to obtain sound locations to the rear of the base, such as the location of a supported battery, a plot is made to the front at G' (fig. 64(a)) and a perpendicular to the base drawn through the plot crossing the base at H. On this line, the true sound source is located at G, a distance GH, equal to $G'H$, to the rear of the base.

b. Curved or irregular base. A sound from the rear recorded on a curved or irregular base will result in a scattered plot. (See fig. 64(b).) To determine the location of such a sound source, the signs of all time intervals are reversed, and a plot made. The rays will diverge toward the front (fig. 64(c)) and each ray must be extended to the rear, intersecting at the sound source G.

88. PLOTTING BALLISTIC WAVES AND SHELL BURST WAVES. a. Application. Under certain weather conditions, ballistic waves and shell burst waves may be recorded for long range guns, although the gun waves cannot be recorded. In such cases, the following method is an approximate determination of the line of fire. Two lines of fire from one gun to different targets afford an approximate location of the gun. This method is valid only if the direction of fire passes within one sub-base length of the sound base where it crosses the line of the base.

b. Oscillogram reading. A position of zero time is selected on the oscillogram ahead of the first break made by the ballistic wave, and the seconds are numbered on the oscillograms to a point beyond the last break for the shell burst, as shown in figure 65. Readings of times of arrival for the ballistic and shell burst waves are entered on separate computing forms. (See figs. 66 and 67.)

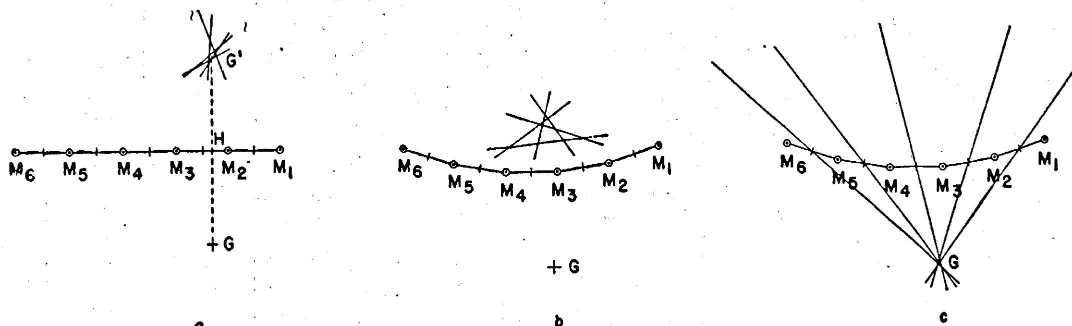


Figure 64. Plotting with sound source to the rear.

c. Plot of shell burst. To locate one point on the line of fire of the projectile, a plot of the shell burst is made in the usual manner. Note that the shell burst may be either

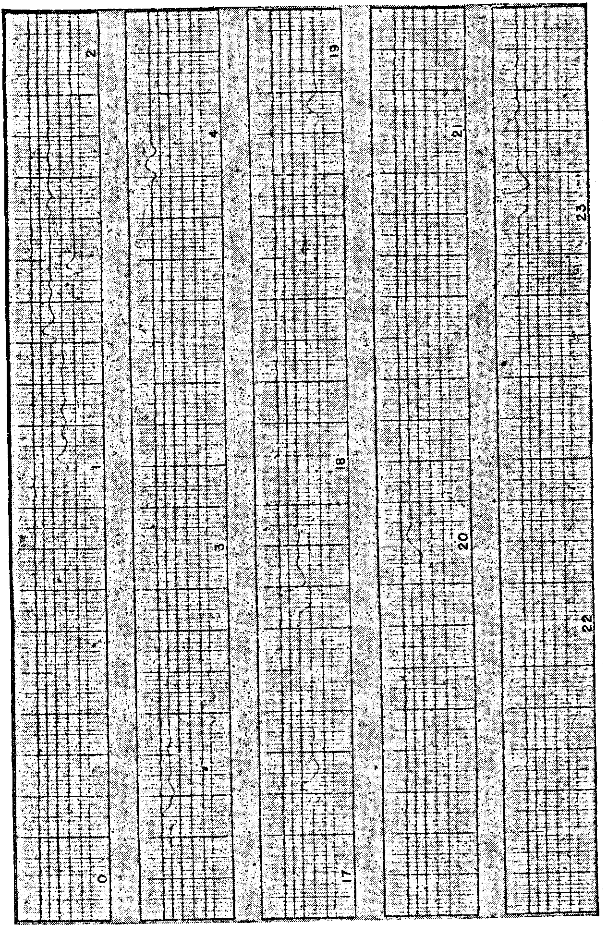


Figure 65. Oscillogram of ballistic wave and shell burst wave.

to the front or rear of the sound base. If a straight sound base is used, the fact that the burst is to the front or rear

of the base must be determined by ear or by visual observation, since it cannot be determined from the oscillogram reading.

SOUND PLOTTING RECORD

Base: Location Grierson Hill Type 6-Mike 4-Second Straight Azimuth 0° 00' 00" Date 8 May 1944

Oscillogram No. 49 Time 2119 Temperature 58 °F Wind: Direction 820 mils Speed 10 mph

Ballistic Wave Time Readings M_1 at 55245.0 - 91415.0

Results to (−)					
X	1. 3.891	2. 2.320	3. 1.292	5 1.450	6 2.569
Results to (+)	4. 0.984	4. 0.984	4. 0.984	4. 0.984	4. 0.984

	1 +	1 −	2 +	2 −	3 +	3 −	5. +	5. −	6. +	6. −
Time Interval	2.907		1.336		0.308		0.466		1.585	
Curvature Correction										
Temperature Corr.	0.023		0.010		0.002		0.004		0.012	
Wind Correction										
Sub-Totals										
Subtract										
Corrected Time Interval	2.930		1.346		0.310		0.470		1.597	
~~Approximate Range~~ Radius	1082		497		114		174		590	

Coordinates: X ____ Y ____ Accuracy ____ yards Caliber 155 Gun File No. ____

Area Shelled ____ No. of Pieces ____ Time Reported ____ Conc. No. ____

FAB Form No. 4 FAB, Fort Sill, Okla., (6-10-44—106,000)—39413 867-868-A

Figure 66. Computing form for ballistic wave.

d. Plot for ballistic wave. On the computing form for the ballistic wave (fig. 66) the time intervals are computed between the first break and each of the other breaks. These intervals are corrected for temperature in the usual way. No wind correction is applied because no simple method of

determining such a correction has been devised. For each microphone, a distance in yards corresponding to the cor-

SOUND PLOTTING RECORD

Base: Location *Grierson Hill* Type *6-Mike 4-Second Straight* Azimuth *0° 00' 00"* Date *8 May 1944*

Oscillogram No. *49* Time *2119* Temperature *58* °F Wind: Direction *820* mils Speed *10* mph

Shell Burst Time Readings *M₁ at 55245.0 - 91415.0*

Results to (−)		22.989	19.883	17.633		
	1 22.989	2 19.883	3 17.633	4 17.166	5 18.809	6 21.692
Results to (+)					17.166	18.809

	1 +	1 −	2 +	2 −	3 +	3 −	4 +	4 −	5 +	5 −
Time Interval		3.106		2.250		0.467	1.643		2.883	
Curvature Correction		0.019		0.041		0.018	0.044		0.027	
Temperature Corr.		0.024		0.018		0.004	0.013		0.023	
Wind Correction		0.037		0.037		0.037		0.037		0.037
Sub-Totals							1.700	0.037	2.933	0.037
Subtract							0.037		0.037	
Corrected Time Interval		3.186		2.346		0.526	1.663		2.896	
Approximate Range	4200		3200		2600		2900		3700	

Coordinates: X *52750* Y *95435* Accuracy *50* yards Caliber *155 Gun* File No.

Area Shelled No. of Pieces Time Reported Conc. No.

FAB Form No. 4 FAB, Fort Sill, Okla., (6-10-44—108,000)—29412 367-368-A

Figure 67. Computing form for shell burst.

rected time interval is found by multiplying the interval by 369.2. Using this distance as a radius and the plotted microphone position as a center, an arc is drawn to the front of each microphone. (See fig. 68.) A smooth curve *PQ* is drawn tangent to all of these arcs with the aid of a flexible drafting curve.

e. Determining line of fire. Using the plotted position of the shell burst (*B* in fig. 68) as a center, an arc is drawn intersecting curve *PQ* at two points, *R* and *S*, not more than 2 or 3 inches apart. (If this is not possible, see f below.) Two arcs of equal radius are drawn using *R* and

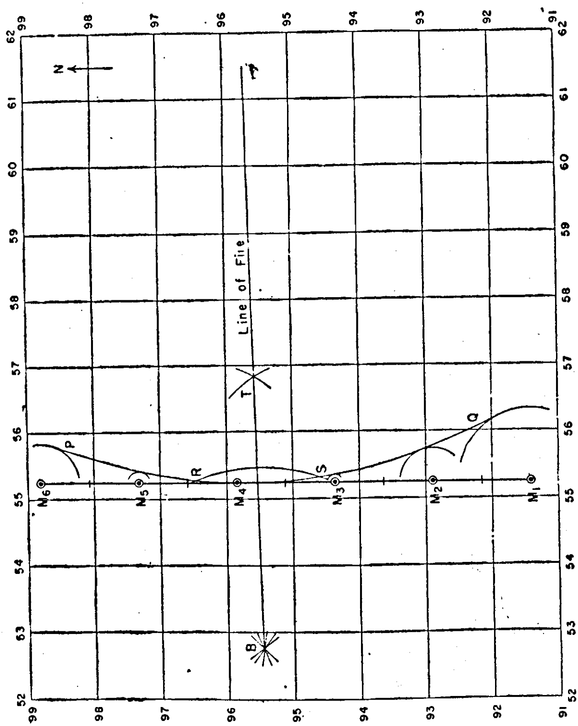


Figure 68. Line of fire determined from ballistic wave and shell burst wave.

S as centers. From their intersection at *T*, a line is drawn to *B*. Line *BT* is the required line of fire (or its extension).

f. Special case in which line of fire does not cross base. (1) If the line of fire (or its extension) does not cross the sound base, a circular arc drawn with *B* as the center can be made to intersect curve *PQ* at only one point,

regardless of the radius chosen. In such a case, the procedure described in e above is replaced with the following:

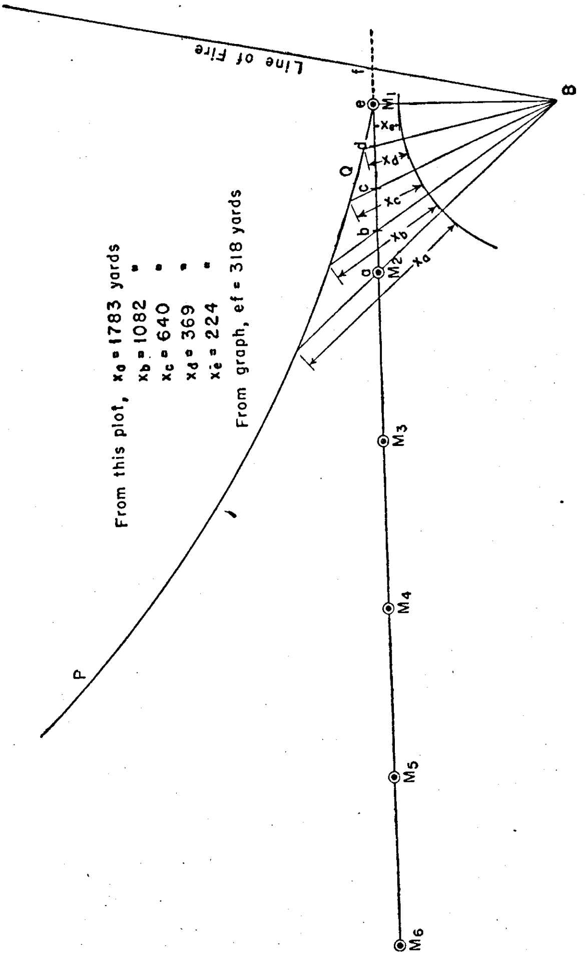


Figure 69. Plot for special case where line of fire does not cross the sound base.

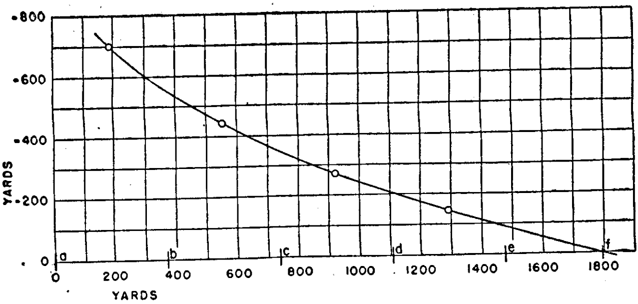
(*a*) An arc is drawn with *B* as the center, using a radius which will not cause the arc to intersect curve *PQ* but

to come close to one end of it where it approaches parallelism. (See fig. 69.) At the end of the curve, the end sub-base is divided into four equal parts by points *a, b, c, d,* and *e.* A straight line is drawn from *B* through each of these points, cutting both the arc and the curve *PQ*. The distance along each of these lines between the arc and the curve *PQ* is measured and recorded as x_a, x_b, x_c, x_d, and x_e, respectively. Their differences $(x_b - x_a)$, $(x_c - x_b)$, $(x_d - x_c)$, and $(x_e - x_d)$ are computed.

(*b*) On a separate sheet, a graph is drawn with the line *ae* and its intermediate points along the horizontal axis. (See fig. 70.) A point is plotted a distance $(x_b - x_a)$ directly above the midpoint of line *ab*. Similarly, a point is plotted a distance $(x_c - x_d)$ above the midpoint of line *bc*, and so on for each of the four sections of the line *ae*. Note that in this graph a larger scale may be used for distances along the vertical axis than for distances along the horizontal axis. A smooth curve is drawn through the four plotted points and is extended until it cuts the horizontal axis at *f*. The distance *ef* (or *af* if *a* is at the end microphone of the sound base) is scaled.

(*c*) Point *f* is transferred to the original plot (fig. 69) on the extension of the line of sub-base *ae*. A line from *f* to *B* is the required line of fire. If point *f* is more than one sub-base length from the end microphone, this method becomes inaccurate and should not be used.

(2) The procedure presented in (*a*) and (*b*) above, is a graphical means of determining the point on the extension of sub-base *ae* opposite which the arc and curve *PQ* are parallel. The first derivative of the distance measured along a radius of the arc from the arc to curve *PQ*, with respect to the distance along *ae* extended, is equal to zero at that point.



From plot of Figure 69

$ab = bc = cd = de = 369.2$ yards

$x_b - x_a = -701$ yards $x_c - x_b = -442$ yards

$x_d - x_c = -271$ yards $x_e - x_d = -145$ yards

From graph above:

$ef = 1795 - 1477 = 318$ yards

Figure 70. Graph for special case, where line of fire does not cross the sound base.

89. DETERMINATION OF CALIBER FROM PLOT OF GUN WAVE AND SHELL BURST WAVE. Whenever an oscillogram is obtained on which both the pattern of a gun wave and of the corresponding shell burst wave can be identified, an estimate of the caliber and type of the piece which fired the round may be made by application of the method described below:

a. Oscillogram reading and determination of range. A position of zero time is selected on the oscillogram ahead of the first break of either the gun or shell burst wave, whichever appears first, and the 1-second intervals are numbered consecutively to a point beyond the last break of the second pattern. Readings for the two waves are entered in separate computing forms and locations corrected in the normal manner are plotted on the plotting board. The range at which the piece was fired is determined by scaling the distance between the gun and

shell burst locations. No correction for difference in altitudes of the gun and the burst need be made unless it changes the measured range by more than 50 yards. When a straight base is used, it is necessary to determine by ear,

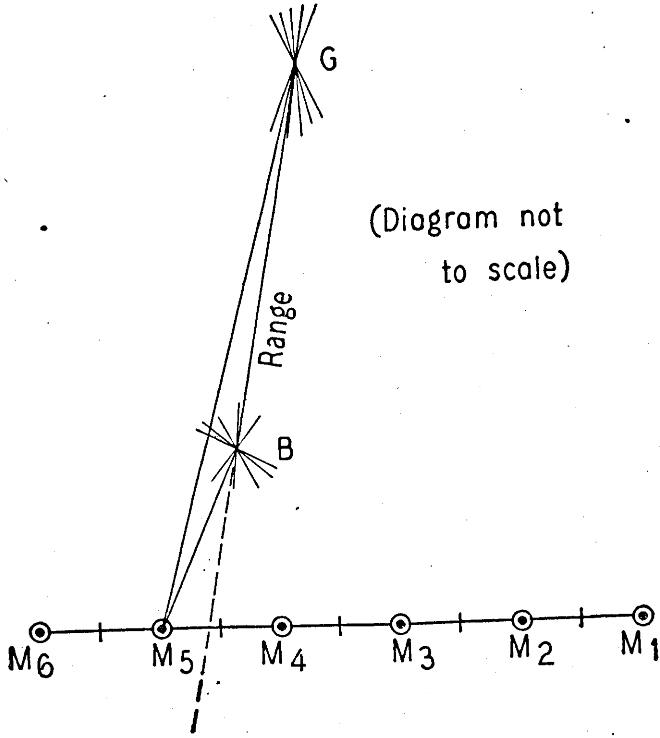


Figure 71. Plot of gun position and shell burst location.

by visual observation, or by an offset microphone whether the shell burst is in front or in rear of the base.

b. Determination of time of flight. (1) *Theory.* While the time at which the projectile and gun wave left the gun is unknown, the difference in arrival times of the gun wave

and shell burst wave at a given microphone may be determined by taking the difference between breaks of the two waves on the same line of the oscillogram.

Referring to figure 71, if standard atmospheric conditions are assumed, the time required for the gun wave to travel the distance from the gun to the microphone M_5 is:

$$T_g = \frac{GM_5}{V} \qquad (1)$$

where V is the velocity of sound. The time at which the burst wave arrives at M_5 is:

$$T_b = T_f + \frac{BM_5}{V} \qquad (2)$$

where T_f is the time of flight of the shell. If the gun wave arrives ahead of the burst wave, the difference in arrival times,

ΔT, is:

$$\Delta T = T_b - T_g = T_f + \frac{BM_5}{V} - \frac{GM_5}{V}$$

and

$$T_f = \left(\frac{GM_5}{V} - \frac{BM_5}{V}\right) + \Delta T \qquad (3)$$

If the burst wave arrives ahead of the gun wave:

$$\Delta T = T_g - T_b = \frac{GM_5}{V} - T_f - \frac{BM_5}{V}$$

and

$$T_f = \left(\frac{GM_5}{V} - \frac{BM_5}{V}\right) - \Delta T \qquad (4)$$

A computation of T_f, from whichever of equations (3) or (4) is applicable may be made for each microphone but results of sufficient accuracy can be obtained from a single computation if the microphone *nearest the line of flight* (or its extension) is used.

(2) *Computations.* To determine the time of travel of each sound wave, the distances (in yards) from the points of origin of the waves to the microphone selected for computations are scaled on the plotting board and each distance is divided by 369.2 to give the travel time in seconds. The difference in arrival times (ΔT above) is added to (or subtracted from) the difference in travel times to give the time of flight.

Note. Weather corrections should be applied to obtain the plotted locations of the gun and shell burst, but the accuracy required in the time of flight does not justify correcting the velocity of sound in equations (1) and (2). Also, since the projectile is subject to the same meteorological conditions as the sound, neglect of weather corrections in the time of flight computation will often tend to compensate for deviations from the standard time of flight as determined from firing tables.

c. Application and expected accuracy. (1) Use of this method of determining caliber and type of artillery depends upon the availability of information regarding the characteristics of enemy weapons. Time of flight often can be determined from a single oscillogram to within an error of a few tenths of a second but an average from several oscillograms is more reliable. This degree of accuracy is usually sufficient to distinguish between pieces firing at ranges in excess of 3,000 to 4,000 yards, but is of little or no value for shorter range fire. It should be noted, however, that on a front where the enemy might be using artillery of different nations it may prove necessary to find out from other sources of information what types of artillery are in use in the sector. It will be found helpful, in practice, to plot on a single sheet a series of curves of time of flight versus range for all known weapons. After computations have been made, the most likely weapon can be spotted from the graph without the necessity of searching through firing tables.

(2) The method of caliber determination described above

does not depend upon the fidelity of response of the microphones, as does the method described in paragraph 82. Estimates of caliber by this method should, however, be verified from other sources of intelligence.

d. Example: An example of the computation of time of flight is shown below. Referring to figure 71 (not to scale), the gun and shell burst locations have been plotted with data shown in the sound plotting records, figure 72. Since the extended line of flight, *GB*, crosses the sound base nearest to M_5, data pertaining to this microphone are used. With a plotting scale, the lengths of the line M_5G, M_5B, and *GB* are scaled.

Range $GB = 6{,}510$ yards

Range M_5G	12,598 yd
Time of travel $= \dfrac{12598}{369.2} =$	34.122 sec
Range M_5B	6,086 yd
Time of travel $= \dfrac{6086}{369.2}$	16.484 sec
Oscillogram reading—gun	0.148 sec
Oscillogram reading—shell	2.676 sec
Difference in arrival times	+2.528 sec
Difference in travel times	17.638 sec
Time of flight	20.166 sec

From firing tables (or graph constructed as described above), the time of flight for 155-mm howitzer, M1, charge 5, at a range of 6,500 yards, is 20.0 seconds. Time of flight for the 105-mm howitzer, M2, charge 6, at 6,500 yards, is 20.6 seconds. The piece firing the round might have been either, but probably was not a 155-mm howitzer, M1917, whose time of flight for charge 6, at 6,500 yards, is 18.8 seconds.

Gun

SOUND PLOTTING RECORD

Base: Location 845 Type 4 Sec. Straight Azimuth 2° 25' 20" Date 6 Aug. 1944

Oscillogram No. 103 Time 1500 Temperature 97 °F Wind: Direction 3000 mils Speed 07 mph

Time Readings

Results to (−)	3.090	1.760	0.771	0.264	
1 3.090	2 1.760	3 0.771	4 0.264	5 0.148	6 0.508
Results to (+)					0.148

	1 +	1 −	2 +	2 −	3 +	3 −	4 +	4 −	5 +	5 −
Time Interval		1.330		0.989		0.507		0.116	0.360	
Curvature Correction		0.002		0.001		0.001				
Temperature Corr.		0.063		0.047		0.024		0.006	0.017	
Wind Correction		0.035		0.035		0.035		0.035		0.035
Sub-Totals		1.430		1.072		0.567		0.157	0.377	
Subtract									0.035	
Corrected Time Interval		1.430		1.072		0.567		0.157	0.342	
Approximate Range										

Coordinates: X____ Y____ Accuracy____ yards Caliber____ File No.____

Area Shelled____ No. of Pieces____ Time Reported____ Conc. No.____

FAS Form No. 6

(A)

Shell Burst

SOUND PLOTTING RECORD

Base: Location 845 Type 4 Sec. Straight Azimuth 2° 25' 20" Date 6 Aug. 1944

Oscillogram No. 103 Time 1500 Temperature 97 °F Wind: Direction 3000 mils Speed 07 mph

Time Readings

Results to (−)	8.512	6.103	4.213	3.048	
1 8.512	2 6.103	3 4.213	4 3.048	5 2.676	6 3.235
Results to (+)					2.672

	1 +	1 −	2 +	2 −	3 +	3 −	4 +	4 −	5 +	5 −
Time Interval		2.409		1.890		1.165		0.372	0.559	
Curvature Correction		0.006		0.007		0.007		0.002	0.004	
Temperature Corr.		0.114		0.090		0.056		0.018	0.027	
Wind Correction		0.035		0.035		0.035		0.035		0.035
Sub-Totals		2.564		2.022		1.263		0.427	0.590	
Subtract									0.035	
Corrected Time Interval		2.564		2.022		1.263		0.427	0.555	
Approximate Range										

Coordinates: X____ Y____ Accuracy____ yards Caliber____ File No.____

Area Shelled____ No. of Pieces____ Time Reported____ Conc. No.____

FAS Form No. 6

(B)

Figure 72. Computations for gun and shell burst locations.

90. SOUND PLOTTING CHART. a. General. To facilitate handling of fire missions, a sound ranging unit may use as a plotting chart a grid sheet, photomap, or battle map corresponding to the firing chart used in the fire-direction center of the supported unit. A plain gridded surface is preferable.

b. Observed fire chart on grid sheet. When a firing unit is using a grid sheet as an observed fire chart, the sound unit may plot on the same grid system by preparing the sound plotting chart in the following manner: A sound plot of a base (check) point is made on the plotting board. The base (check) point is also plotted on a transparent grid sheet at the chart location reported by the fire-direction center.

(1) If the grid is oriented on *Y*-north, a line is drawn on the transparent grid at the *Y*-azimuth of the sound base, in the proper position relative to the base (check) point on the sound plotting board, and rotated until the azimuth line on the grid sheet is parallel to the sound base on the sound plotting board.

(2) If the grid is oriented on an arbitrary chart direction by firing, the position of the gun which fired the rounds on the base (check) point may be plotted on the sound plotting chart and its line of fire drawn from the gun to the base (check) point. The gun position may fall off the sound plotting chart, in which case a separate chart may be necessary in order to determine graphically the direction of fire from the plotted positions of sound base, gun, and base (check) point. A line representing the direction of fire is then drawn through the base (check) point on the sound plotting chart. A similar line is back plotted on the grid sheet from the plotted position of the base (check) point, from the back azimuth of the direction of fire as reported by the firing unit. The base (check)

point on the transparent grid sheet is then superimposed over the plotted position of the base (check) point on the sound plotting board and rotated until the lines of fire coincide.

c. Photomap as a sound plotting chart. The sound base may be plotted on a photomap, or a photomap may be attached to a sound plotting board and prepared for plotting with a sound ranging fan. Sound records are obtained of a base (check) point identifiable on the photomap and the sound plot is forced through the proper location.

d. Battle map as a sound plotting chart. The sound base may be plotted on a map and the map prepared for plotting with a fan. When the base is surveyed by hasty methods, a plot is usually forced through the map location of the base (check) point, based on records from several rounds fired.

e. Grid sheet as a sound plotting chart. A grid may be constructed on the face of the plotting board (g below) either in pencil or india ink, or on a sheet of drafting cloth or paper.

f. Positioning map or grid sheet on plotting board. (1) When the positions of the midpoints on the plotting board are fixed, as is the case with the mechanical plotting board or improvised plotting board, the scale of the grid must correspond to the scale at which the midpoints are spaced. The map or grid sheet may be correctly positioned on the board as follows: To the azimuth of a sub-base (usually M_3 or M_4) add 90°. Determine the angle from the resulting azimuth to the nearest grid line direction. Set the plotting arm at the computed angle from the reference line of the sub-base. On the mechanical plotting board this is done with the degree scale on the board. On other boards it is done with a range-deflection fan. On the map or grid

sheet, a point is plotted a convenient distance from the midpoint, in the direction of the determined grid line. Draw a ray from this point parallel to the grid lines, toward the midpoint, and extend it in the opposite direction. Place the map or grid sheet under the plotting arm with the line along the edge of the arm, with the plotted point the correct distance from the midpoint. Affix the grid sheet to the board.

(2) *Example.* The azimuth of a curved base is 201° 20′. The azimuth of the reference line from C_3 is 201° 20′ plus 90°, or 291° 20′. The nearest grid line direction is 270° or 21° 20′ less than the azimuth of the reference line. The plotting arm is set at 21° 20′, through C_3 to the left of the reference line. The coordinates of C_3 are 205,343.2 — 403,439.0. A point 5,000 yards west of C_3 is selected, at coordinates 200,343.2 — 403,439.0. It is plotted on the grid sheet, and an east-west line drawn through it. The grid sheet is placed under the plotting arm with this line along the edge of the arm, and with the plotted point at the 5,000-yard mark on the range scale.

g. Construction grid on plotting board. When time permits, a grid is constructed directly on the plotting surface of the board. One method is described in TM 9–2684. The following method is more rapid (fig. 73):

(1) As in f(1) above, compute the angle between the reference line of sub-base M_1M_2 and a grid line direction. For a curved base the direction selected should be that which is nearest the reference line of the center sub-base. The plotting arm is set at the computed angle and a long ray drawn from C_1. The same procedure is followed for the sub-base on the opposite flank.

(2) Select a grid line perpendicular to the rays drawn, at a convenient distance in front of the base. From the

coordinates of the midpoints, compute the distance from each of the two midpoints to the grid line. Mark off this distance on each ray, thus locating the grid line. Other parallel grid lines are laid off at 1,000-yard intervals.

(3) Compute the distance from each of the two rays to the next grid line parallel to it. Scale off these distances to fix points through which the grid lines should pass, and draw the grid lines parallel to the original rays. Draw parallel lines of 1,000-yard intervals to complete the grid.

(4) The grid must be inked if time permits. Inked grids are removable with alcohol.

(5) *Example.* A 4-second straight base has an azimuth of 278° 15′. The coordinates of C_1 are 273,588.4 — 162,090.7 and of C_5 are 267,742.4—162,938.3. The azimuth of the base plus 90° is 368° 15′ or 8° 15′. The grid line direction nearest this azimuth is north, which is 8° 15′ to the left. Rays are drawn from C_1 and C_5 8° 15′ left of the reference lines. A grid line perpendicular to the rays drawn, and in front of the base, is north of both midpoints. The 165,000 grid line is selected. Comparison of this value with the Y coordinates of C_1 and C_5 shows it to be 2909.3 yards north of C_1 and 2061.7 yards north of C_5. These distances are measured along the corresponding rays from C_1 and C_5. The 165,000 grid line is drawn through these points, and parallel grid lines are laid off at 1,000-yard intervals. The ray from C_1 is at an X coordinate of 273,588.4, 411.6 yards left of the 274,000 grid line. This distance is measured and marked. Similarly, a distance of 742.4 yards is measured to the left of the ray from C_5 to locate the position of grid line 267,000. The distance between the two marks is measured to verify that the positions for grid lines 267,000 and 274,000 are accurately 7,000 yards apart. These grid lines are drawn parallel to the two rays, and other parallel lines are drawn at 1,000-yard intervals to complete the grid.

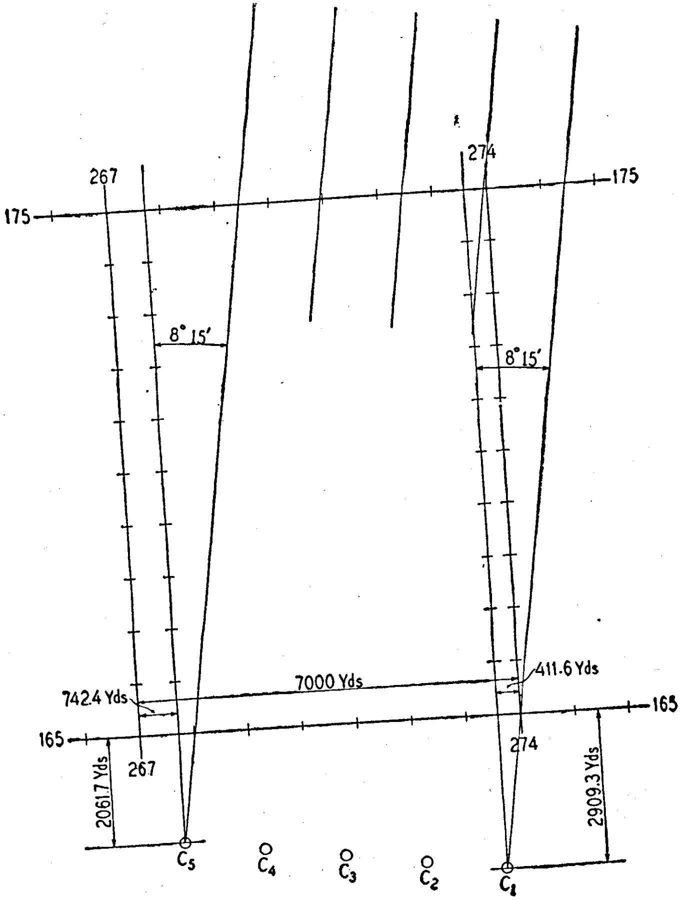


Figure 73. Constructing grid on plotting board.

91. REGISTERING ON BASE POINTS AND CHECK POINTS. a. When the sound ranging unit has a mission of supporting a particular firing unit, the firing unit should assist the sound ranging unit by registration. This will provide the sound ranging unit with a chart location of the

firing unit's base or check point. If the firing unit uses a precision adjustment, each round of fire for effect may be recorded and plotted. Occasional plots are made of fire on check points and targets. These plots may be used as reference points from which locations of subsequent targets may be sensed if no appreciable changes in weather conditions occur. Reference lines may be adjusted by forcing a plot through the true chart location of a point. These points may be used to determine wind corrections if the true chart location is known and the interval survey of the base is accurate.

b. Whenever sound records are desired on a base point or check point, the sound ranging unit may request "Mark base (check) point number............, Two rounds at my command, Report time of flight and on the way"; or "Fire two rounds in center of sector, Range 8000, Report time of flight and on the way," and proceed in the normal manner for a base point registration.

Section V. CONDUCT OF FIRE

92. GENERAL. The same general principles apply in the conduct of fire by sound ranging as by flash ranging. An adjustment may be made on the target, or a registration on an auxiliary target followed by a transfer to bring surprise fire on the target.

93. REPORTING TARGETS. a. General. Targets located by sound ranging are normally reported by coordinates. In the absence of a coordinate system common to both sound ranging and firing units, sensings may be made in relation to a base point (check point or reference point). The number of plots and accuracy of location should be given, and the number of guns, type, and approximate caliber should be announced if known. If conditions are favorable for a

sound ranging adjustment, "Will adjust" should follow the report of the target.

Note.—In survey and computation of sound bases, coordinates and distances are expressed in yards. When reporting locations of targets by coordinates, coordinates are given in short form (for example, 57.46 — 38.75).

b. Prearrangement. When the battalion is operating under centralized control, targets are reported to observation battalion operations section. Missions are evaluated and transmitted to corps artillery fire-direction center, which assigns the mission to a firing unit, specifies the type of mission, the number of rounds to be fired, the channel of communication to be used, and designates a concentration number. Under decentralized control, when an observation battery is assigned to support an artillery unit, targets are reported directly to the fire-direction center of the supported unit.

c. Accuracy of location. The estimated accuracy of the location of a target is expressed as the number of yards it is estimated that the determined location of the target may vary from the true location of the target; as: within 50 yards, within 100 yards, within 150 yards, and over 150 yards. The estimate of the accuracy of location is based on an estimate of the accuracy of survey, length of sound base, distance to the sound source, weather conditions, readability of the oscillograms, appearance of oscillogram traces, and appearance of the polygon of error. The accuracy of a sound ranging location is somewhat better in deflection (measured from the perpendicular bisector of the base) than it is in range (measured perpendicular to the base). Thus, a reported accuracy of 50 yards may represent a possible error of 50 yards in range, but only 20 to 30 yards in deflection.

94. SOUND RANGING ADJUSTMENT. An adjustment should be completed as soon as possible to avoid effect of

changes in weather conditions. Adjustment is by single piece firing groups of two or more rounds or by platoon or battery salvos. The firing unit reports time of flight, azimuth of fire and "On the way" for the initial adjusting round. (A code time of flight is used with radio communication.) The sound ranging unit reports its sensings using forward observer methods. The adjustment is continued until the sound ranging unit estimates that the next shift will obtain effect on the target, at which time the next sensing will be followed by the command "Fire for effect." A bracket is desirable in order to avoid possible error due to undetermined altitudes and to distortions of the sound wave by local terrain features.

95. SURVEILLANCE OF FIRE. A heavy concentration of fire produces complicated oscillograms. If the oscillograms obtained from fire for effect are not usable, the sound unit requests one or more single rounds at the center of impact of the concentration, after the completion of fire for effect, to check the accuracy of the fire.

96. TRANSFER OF FIRE. If surprise fire is desired, an auxiliary target may be selected by the observation unit. This is done with the assistance of the firing unit. The auxiliary target then becomes a point at which a center of impact registration is fired. This point is selected about 500 yards from the target and on terrain similar to that in the vicinity of the target itself, in order to prevent errors resulting from differences in site. A transfer of fire is then made from the auxiliary to the real target.

97. EXAMPLE. An enemy gun battery is located by Baker Sound. The accuracy of location is estimated as within 100 yards. It is reported to the observation battalion command post as follows:

Sound Report, Coordinates 75.46—90.62, Enemy battery, Three plots, Estimated accuracy 100 yards, Time observed 0510, Will adjust.

The report is evaluated and reported to corps artillery fire-direction center.

Sound Report, Coordinates 75.46—90.62, Enemy battery, Located by Baker Sound, Estimated accuracy 100 yards, Time observed 0510, Will adjust.

Corps artillery fire-direction center directs the 170th Field Artillery Battalion to fire the mission and notifies the observation battalion accordingly. A concentration number is assigned and surprise time fire is specified, as well as the number of rounds to be fired and the channel of communication to be used. Direct communication should then be established between the sound ranging central and the fire-direction center of the firing unit.

The observation battalion notifies Baker Sound to stand by to adjust the 170th Field Artillery Battalion and furnishes the coordinates of the auxiliary target.

SRC to FDC	FDC to SRC	Remarks
(1) Fire mission, Conc. No. 120, coordinates of auxiliary target 75.96-90.52, two rounds at my command. Report direction of fire and time of flight.	(2) Adjust battalion, Baker. Direction of fire 1280, time of flight 35 seconds. Battery is ready.	The sound plotting team plots the auxiliary target and a line indicating the direction of fire through the auxiliary target.
(3) Fire.	(4) On the way. (5) On the way.	Center of impact of the adjusting rounds is plotted and the sensing is reported.

SRC to FDC	FDC to SRC	Remarks
(6) 300 right, 500 over; fire for effect, when ready.	(7) Battalion firing for effect.	Sound record from fire of a battalion is not readable.
(8) Two rounds from base piece, center range.	(9) On the way. (10) On the way.	Center of impact of the two rounds is plotted, and the sensing is reported.
(11) Deflection correct, 50 short.		Fire for effect is corrected to place center of impact on target.

Note.—If common survey is not completed, the original location may be reported by forward observer sensing with respect to a base or check point.

98. RECORDS AND REPORTS. A record is kept of each target location and adjustment made, on the appropriate record forms. (See sec. VI, chap. 9 and fig. 118.)

Section VI. PROPAGATION OF SOUND IN ATMOSPHERE

99. GENERAL. To understand the capabilities and limitations of sound ranging and to evaluate properly the accuracies of sound locations require a knowledge of the mechanism of propagation of sound in the atmosphere as it is affected by weather elements.

100. SOUND WAVES. a. General. If a disturbance is produced by a local distortion of a continuous elastic medium, this disturbance will be propagated in all directions from its source at a rate which depends upon the physical properties of the medium and not on any characteristic of the source. The propagated wave may or may not

be audible, that is, it may or may not be a sound wave, depending upon the characteristics of the source and not on the properties of the medium. Waves of this type are propagated through elastic solids, liquids, or gases. Artillery sound ranging depends upon measurements made on sound or infrasonic waves propagated through the atmosphere, under whatever conditions happen to exist at the time.

b. Impulse wave. When a gun is fired or a shell bursts, a region of intense pressure is produced. The surrounding air is displaced outward in all directions against air farther away from the point of explosion. Because of the inertia of the air, the outward flow continues until the pressure at the point of explosion has been decreased to a value considerably below normal, and a region of rarefaction has been produced. The air then flows back until the pressure returns to normal or sometimes to a value slightly higher, and then to normal. There is no continuous outward flow of *air*, but there is a continuous outward flow of energy, propagated by successive compression and rarefaction of the air in the neighborhood of each point along any path of the sound. The process described above is closely analogous to that which takes place when a pebble is tossed into a quiet pool. As the pebble begins to sink, the water is raised upward and outward, but seeks to return to its undisturbed position by displacing the water farther away; and a crest moves outward. The initial motion, because of the inertia of the water, produces a trough where the pebble passed through the surface, which follows the crest in its outward motion. Successive crests and troughs are propagated in circles of uniformly increasing radius until the oscillations at the point of origin are damped out. Both of the waves discussed above are impulse waves. A curve representing the variation of pressure with time at a given point on the path of the wave is shown in figure 74.

In the first (acoustic) case, the motion of the air is a vibration of its molecules in a direction parallel to the direction of propagation, and is defined as a *longitudinal*, or *compression* wave. In the second case, the motion of a particle of water is in a circle or ellipse in a vertical plane, a combination of *longitudinal* and *transverse* oscillations.

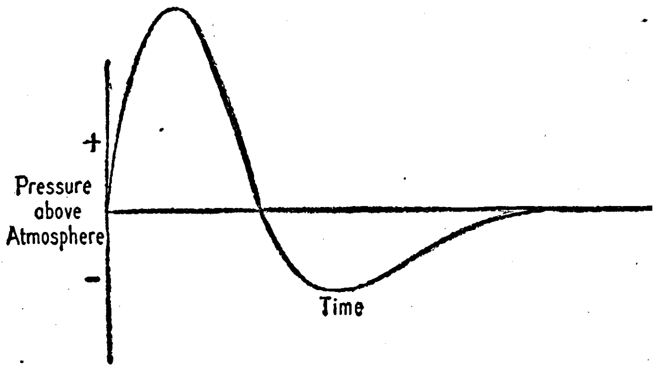


Figure 74. Impulse wave.

c. Characteristics of sound. (1) *Continuous wave.* A sound wave from a continuously vibrating source is similar to the impulse wave described above except that it is not damped out. A wave of this type is represented in figure 75 (A).

A vibrating reed at the end of a long pipe compresses the air ahead of it as it moves to the right, and a wave of compression travels down the pipe. As the reed moves to the left, the pressure drops, and a rarefaction is produced, which follows the compression at the same speed. The distribution of pressure along the pipe at a given instant is shown in figure 75 (B). As time progresses, the entire curve in figure 75 (B) can be pictured as traveling to the right with the wave velocity. A graph of the variation of pressure with time at a *fixed point* in the pipe would be similar in appearance to the curve of figure 75 (B).

(2) *Amplitude, frequency, phase, and wave length.* At a fixed point in the path of the wave, the molecules in the air may be pictured as vibrating in a direction parallel to the path of the wave. The *amplitude* of vibration is the maximum displacement of a molecule to right or left of its mean position. Similarly, the amplitude of oscillation of the pressure is its maximum variation from the mean atmospheric pressure (zero line on the curve of figure 75 (B)).

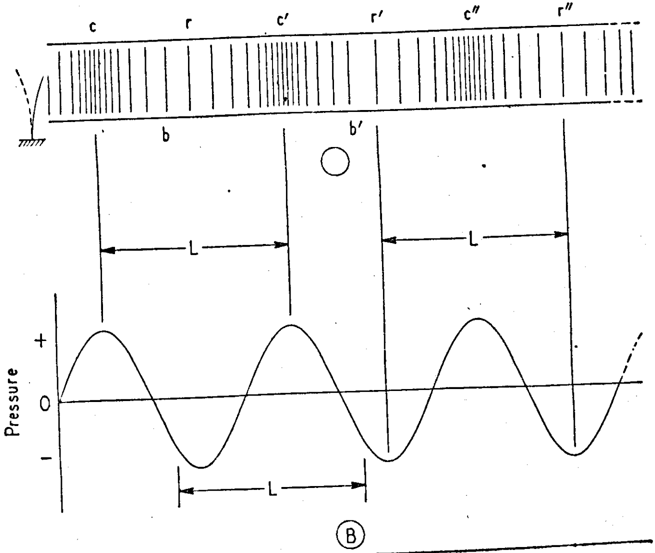


Figure 75. Continuous wave.

The *frequency* of oscillation is the number of oscillations completed in a unit time. Its reciprocal, the *period,* is the time required for one complete oscillation, that is, for a particle to travel from its zero position to each extreme and back to zero, or for the pressure to increase from the mean or zero to the maximum, to minimum, and to return to the mean. Two vibrating particles are said to be in the same

phase when they have the same displacement and are moving in the same direction, and are completely out of phase when they have the same displacement in opposite directions. Thus particles at c, c', and c'' are in the same phase, as are those at r, r', and r'', and those at b and b'. The *wave length* of a wave is the *shortest* distance along the line of propagation between two particles vibrating in the same phase, designated by L in figure 75. Wave velocity, V, wave length, L, and period, T, (or frequency, n) are related by the equation

$$L = VT$$

or

$$L = \frac{V}{n}$$

The range of audible frequencies is approximately 20 vibrations per second to 20,000 vibrations per second, although some individuals can hear sounds of lower or higher frequency. Microphones used in sound ranging are designed to respond to frequencies in the range from 5 to 25, with maximum response between 10 and 15 cycles per second. Some microphones are provided with an adjustment to raise the upper limit of response to about 60 cycles per second, which gives a somewhat better ratio of signal strength to noise. The wave length of a 15-cycle sound wave under standard conditions is 73.8 feet.

101. SOUND PATHS. a. If temperature and humidity are constant and uniform throughout the atmosphere, and if there were no winds or air currents, the speed of propagation of sound through the air would be the same in all directions, and all corresponding points on a wave of compression or rarefaction would travel equal distances in equal times.

b. If a *wave front* is defined as a surface passing through

all points vibrating in the same phase which originated at the source at the same time, then a above can be stated more simply as follows: Under the conditions given, the propagated wave fronts are spheres of uniformly increasing radius. The path of any given point on a wave front as it moves away from the source is a *sound path* or *sound ray.* In the case above, the sound rays are straight lines, the radii of the spherical wave fronts.

102. VARIATION OF VELOCITY OF SOUND. Mathematical formulae which express the speed of sound as functions of temperature and of wind velocity are given in paragraph 83d. Application of these formulae to sound ranging is based on an assumed constant "effective" temperature and an assumed uniform "effective" wind. These assumptions frequently give poor results because the effect of variation (in space) of temperature and wind causes the sound path to curve rather than to follow a straight line. In general, if the combined effect of weather elements is such that the velocity of sound is less at the surface of the earth than it is higher up, then the upper portions of a wave front will move ahead of those lower down, and rays are deflected, or *refracted,* downward. This condition is the one most favorable for sound reception. It may result from one or more of the following causes:

1. Temperature increases with altitude.
2. Wind and sound are moving in the same directions and wind velocity increases with altitude; or
3. Wind and sound are moving in opposite directions, but wind velocity decreases with altitude.

Sound paths and wave fronts for this case are shown diagramatically in figure 76(a). If reverse conditions exist, that is, if

1. Temperature decreases with altitude; or
2. Wind and sound are moving in the same direction but wind velocity decreases with altitude; or
3. Wind and sound are moving in opposite directions and wind velocity increases in altitude; then

the lower portions of a wave front move ahead of those higher up, and the sound is refracted upwards. This effect, which makes sound ranging difficult or even impossible, is illustrated in figure 76(b). In this illustration, the scale of wind velocities has been highly exaggerated, for emphasis. The illustration has been drawn for the wind structures shown in solid lines. The form of the sound waves and of the sound rays, with the wind velocities shown in dotted lines, would be similar.

A cause of multiple arrivals of sound at a microphone is also illustrated in figure 76(a). A microphone located at *M* may receive a direct ray, followed by rays which have been reflected from the ground one or more times and hence require a longer time to travel from the source to the microphone. Another cause of multiple arrivals is a "temperature inversion." During the evening or early morning after a cloudless night, when the winds are very low, a condition may exist in which the air temperature increases with altitude up to a height of 1 or 2 thousand feet, then decreases sharply further up. There is then a tendency for sound waves to be deflected downward below this level and, at longer ranges, multiple arrivals may occur. This condition is favorable for sound ranging, although occasionally, initial breaks may be somewhat obscured by attenuation of the sound due to dissipation during its travel along the inversion level.

103. OTHER EFFECTS IN PROPAGATION OF SOUND.

a. Reflection. Sound waves are reflected from any large sur-

face, such as the side of a large building or a cliff or mountain side. Microphones located to the front of such an ob-

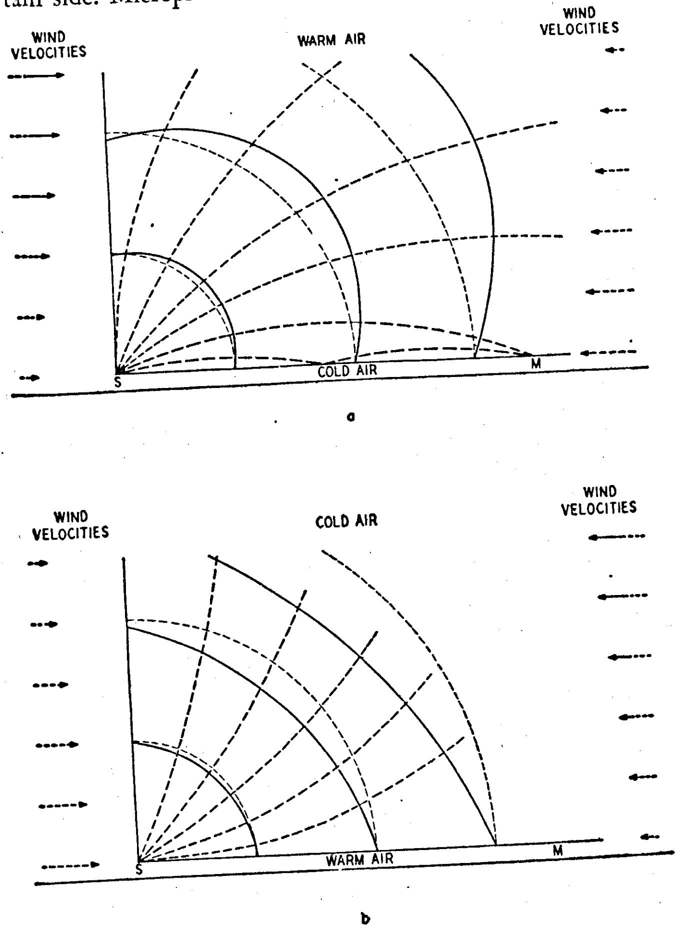


Figure 76. Influence of temperature and wind variations on propagation of sound waves.

ject may thus receive echoes which will confuse the oscillogram. From this point of view, it is better to locate a

microphone on the face or at the foot of a cliff than a few hundred yards in front of it.

b. Interference. Two rays of sound from the same source but traveling by different paths to the same point will interfere. If the two waves arrive in the same phase, one will reinforce the other and the resulting sound will be of greater intensity than either of its components. If they are not in the same phase, one will tend to cancel the other. Thus under certain conditions combination of two such sound waves may result in silence.

c. Diffraction. A sound wave is propagated around relatively small terrain features, such as buildings or small hills of sharp contour, in its path. A sound ray which arrives at a microphone behind a mask has traveled around it; consequently, its travel time is longer than that of a straight line path from the source to the microphone. Time intervals computed for the two sub-bases adjacent to this microphone will be in error, as described in paragraph 83e. Beyond such masks, regions of low sound intensity, or "sound shadows," may be produced by the phenomenon of interference described above. This effect will be most noticeable when the size of the diffracting object corresponds to a few wave lengths of the sound. Microphones located in regions of sound shadow will appear to be very insensitive.

d. Attenuation. Independently of other effects, the ranges at which sound ranging is possible are limited by attenuation of the sound as it is propagated outward from the source. This attenuation results from two causes: (1) Since the total energy flowing out is uniformly distributed over the surface of a spherical wave front, the *intensity* of sound at any point varies inversely as the square of its distance from the source. (2) Energy is absorbed by the medium through which the sound is propagated. The limit-

ing range at which a gun may be located depends upon the amount of energy in the sound and upon the distribution of this energy in the propagated frequencies, since absorption of energy is less for low frequency than for higher frequency sounds.

e. Air currents and turbulence. (1) Turbulent motion in the atmosphere and vertical air currents may occur, to some degree, even during seemingly settled weather. Since there is no available method of applying corrections for such phenomena, they may have an adverse effect on the accuracy of sound ranging locations; the extent of this adverse effect is as yet entirely unpredictable.

(2) During periods of unsettled weather, such as occur when a "front" between air masses of different character is near the area of operations, when clouds are developing and wind and temperature distributions are irregular or rapidly varying, conditions are highly unfavorable for sound ranging. The effects of turbulence and vertical currents on the paths followed by sound cannot be determined quantitatively. Standard weather corrections have no meaning and sound ranging adjustments cannot be made with sufficient accuracy to merit firing.

104. WEATHER FORECASTS AND SOUND RANGING.

a. General. When weather maps are available, they may be used to advantage in planning operations. Such maps do not replace actual meteorological observations obtained while sound ranging but they may be used to determine with fair accuracy the type of sound ranging weather which may be expected during the subsequent period of 18 to 24 hours. Expected surface winds and good or bad sound ranging weather may be associated with certain pressure distributions on the weather map. Forecasts may be made by consideration of the rates of travel of high and low pressure

centers. Rates of travel to be used are based on estimates of weather forecasters, and should be obtained from the same source as the maps.

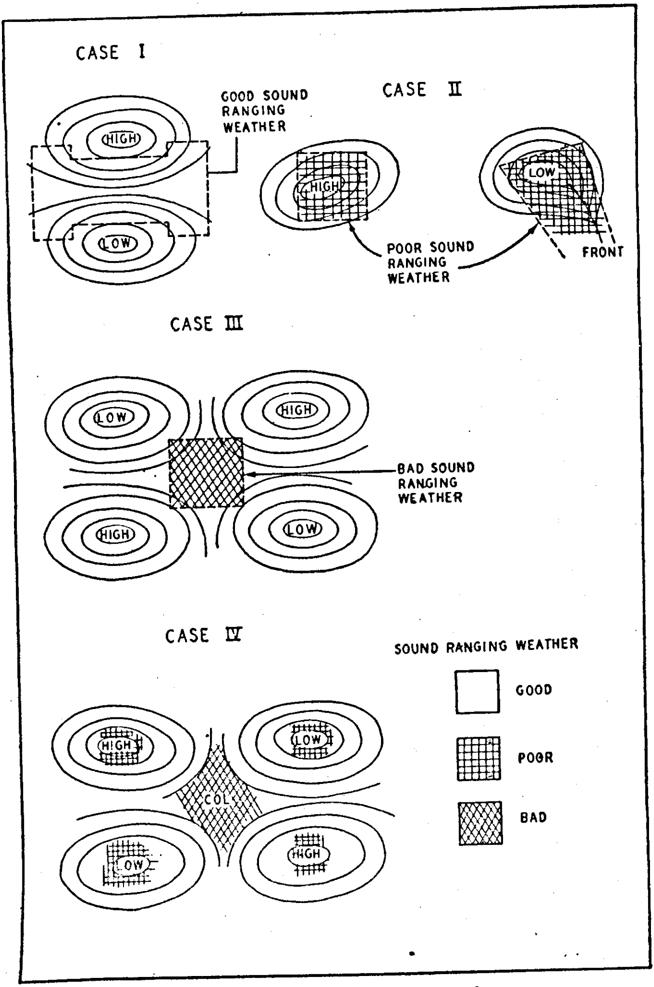


Figure 77. Sound ranging weather.

b. Examples (fig. 77). The following examples of pressure distributions represent typical cases found on weather maps.

Case I. Slightly curved isobars due to a single pressure center indicate "good" sound ranging weather.

Case II. High or low pressure centers or fronts indicate "poor" sound ranging weather.

Case III. A col, or saddle-shaped isobars, due to two like pressure centers, indicates "bad" sound ranging weather.

Case IV. All three conditions are combined into one chart.

105. SOUND WAVES ASSOCIATED WITH GUN FIRE.

a. General. There are several distinct sounds associated with artillery fire, some or all of which may be produced when a single round is fired. Of these, only two, the gun wave and shell burst wave, are of general use in sound ranging. A third, the ballistic wave, may have occasional use. (See par. 88.)

b. Gun wave. The gun wave, or muzzle wave, is the sound produced by the piece when it fires. Gases under high pressure suddenly released from the muzzle create a pressure wave, which is propagated as described in paragraph 100. The shape of the wave front is initially quite complicated but after the sound has traveled a short distance the wave front becomes very nearly spherical, with its center of curvature a few yards ahead of the muzzle. Most of the energy of this sound is in the lower audible and subaudible frequencies. The wave form is smooth and, in general, the larger the gun, the longer is the period of oscillation. (See par. 82e.)

c. Ballistic wave. (1) A projectile whose velocity in flight is greater than the velocity of sound gives rise to a ballistic wave, or shell wave, analogous to the bow wave of

a ship. The presence of a ballistic wave is apparent to an observer near the line of flight of the shell because two distinct sounds are heard. The first, a sharp crack, is the ballistic wave. The second, a lower pitched boom, is the gun wave.

(2) The development of a ballistic wave is illustrated in figure 78. The shell in its flight produces pressure disturbances, each of which is propagated with the speed of sound. Since the shell is traveling faster than sound, a

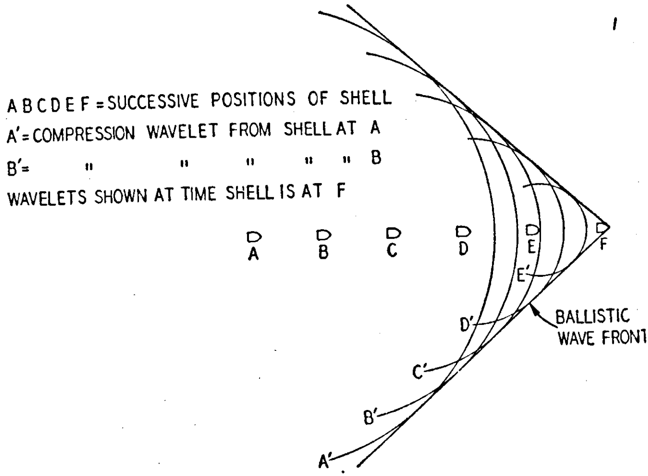


Figure 78. Generation of a ballistic wave.

wavelet from a given point on the trajectory will overlap others from earlier points of origin. They reinforce each other along a line tangent to all wavelets, that is, the resultant ballistic wave is the envelope of the system of spherical wave fronts. If the speed of the shell were constant, the envelope would be a cone tangent to the gun wave and having its apex at the point of the shell. The velocities of actual artillery shells decrease in flight, with the result that actual ballistic waves are shaped like the curves *B* in

figure 79. After the speed of the projectile has dropped below that of sound, no further generation of ballistic wave occurs, but the wave already formed continues on ahead of

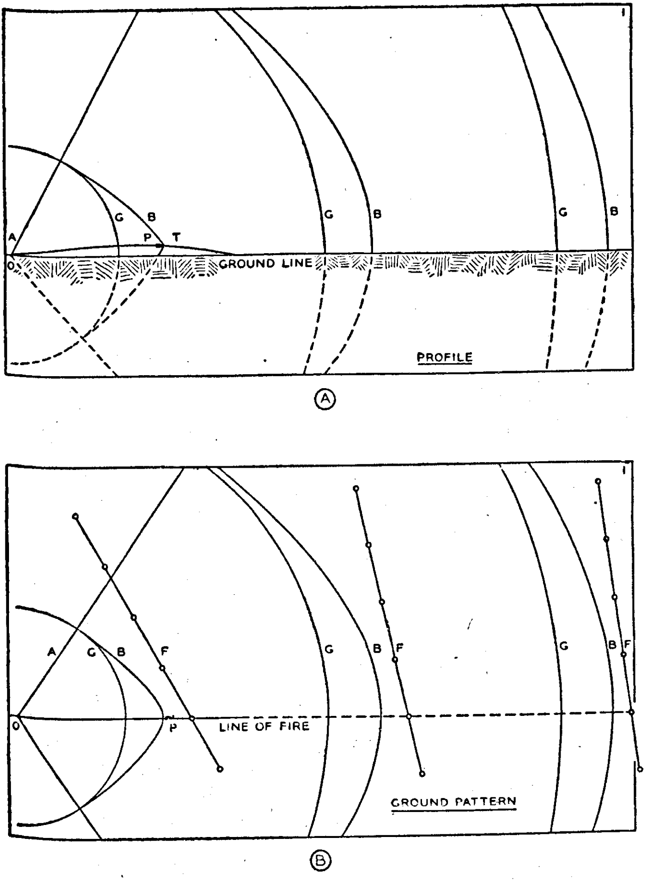


Figure 79. Propagation of ballistic wave.

the gun wave (*B* in fig. 79). Sound bases are represented by the lines *F* in figure 79. A study of this figure will show how the sequence of arrival of sounds at the various micro-

phones varies with the position of the base. A shell whose velocity is always less than that of sound does not generate a ballistic wave, because wavelets of pressure disturbance never overtake those produced at earlier points on the trajectory, and no reinforcement is possible.

(3) Figure 80 is typical of actual photographs of projectiles in flight at speeds greater than that of sound.

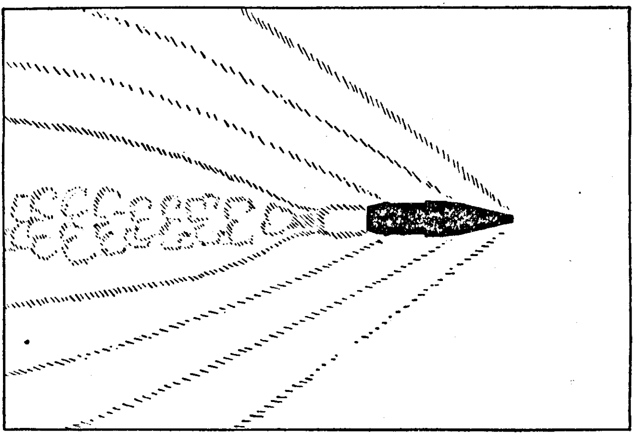


Figure 80. Projectile in flight at speed greater than speed of sound.

(4) Frequency characteristics of ballistic waves are discussed in paragraph 82.

d. Burst wave. (1) The burst wave, or detonation wave, is also an impulse wave, which originates in the bursting of a high-explosive shell. It is similar in some respects to the gun wave, but results from a violent detonation rather than from explosion of a slow-burning propellant charge. The energy of the detonation is distributed over a wider range of frequencies. If sound recording equipment is sensitive to higher frequencies, a more jagged, less smooth record is obtained at short ranges. Because of greater attenuation of high-frequency sounds, however, a record of a shell

burst at a long range is almost identical in form to that of a gun wave.

(2) Another characteristic of burst waves, sometimes observed when a shell burst occurs near to but in front of the sound base, is the presence of *splinter waves*. These are ballistic waves of small amplitude, produced by shell fragments, or splinters, moving faster than sound. Splinter waves, if observed, will appear on the oscillogram as waves of small amplitude just preceding the first large oscillation due to the burst wave, and will usually tend to obscure the first break on the burst wave trace. (See fig. 42(a).)

e. Whistling. A whistling, rustling, or hissing sound associated with the shell in its flight is caused by interference of sound waves within the ballistic wave cone. This sound is of high frequency and is not recorded by sound ranging microphones.

CHAPTER 6

FLASH RANGING

Section I. GENERAL

106. DEFINITIONS. a. Flash ranging. Flash ranging is the procedure employed in locating points in the target area by visual observation and intersection from two or more observation posts. It is employed in locating targets, adjusting friendly artillery, and collecting combat intelligence.

b. Flash ranging location. Flash ranging location is the location of an enemy installation or activity by flash ranging methods.

c. Flash ranging adjustment. Flash ranging adjustment is the location of friendly shell bursts either in the air or on the ground for the purpose of adjusting friendly artillery.

107. GENERAL DESCRIPTION. a. Flash ranging installations are of two general types, rapid installations and deliberate installations. Rapid installations (short base) consist of two observation posts and a small plotting center connected by wire, radio, or both, not necessarily tied to survey control or in communication with observation battery headquarters. Deliberate (long base) installations consist of two or more surveyed observation posts and a plotting center, connected by wire, radio, or both under observation battery control. Selection of the type of installation to be employed is governed by the situation. A long base may be

evolved out of selected observation posts from a series of short bases.

b. In either type installation, each observation post is equipped with an observing instrument for reading horizontal and vertical angles. (See fig. 81.) The instruments are oriented to measure angles to points in the target area. When these angles are plotted, the positions of the points are located. In rapid installations, the instrument of one observation post is oriented with relation to the companion observation post. In deliberate installations, observing instruments normally are oriented with relation to grid north. The observers (fig. 82), having sited a target, report its instrument reading (or azimuth) to the plotting center. There the position of the target is plotted or its range and direction are computed.

Figure 81. Flash ranging observing instrument (spotting instrument M2).

108. GENERAL. Determination of ranges to targets by use of a flash short base is a simple application of the trigonometric sine law relation of oblique triangles, embodying a very short known base in proportion to the ranges sought.

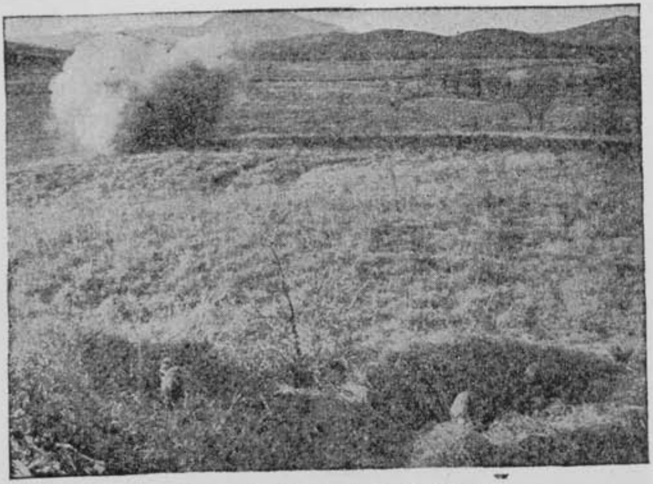


Figure 82. Flash observation post.

a. General considerations. Short base flash ranging is used when conditions are not suitable for long base. These conditions are—

(1) *Time.* A short base requires but a fraction of the time required to install a long base.

(2) *Survey.* A short base is not dependent on common survey control. Locations may be made with reference to points selected in enemy territory, with reference to the flash short base, or plotted directly on a grid sheet, battle map or photomap. Relative locations can be tied readily into

the common survey control when the survey and orientation are brought up.

(3) *Terrain.* When terrain is cut up by woods and hills,

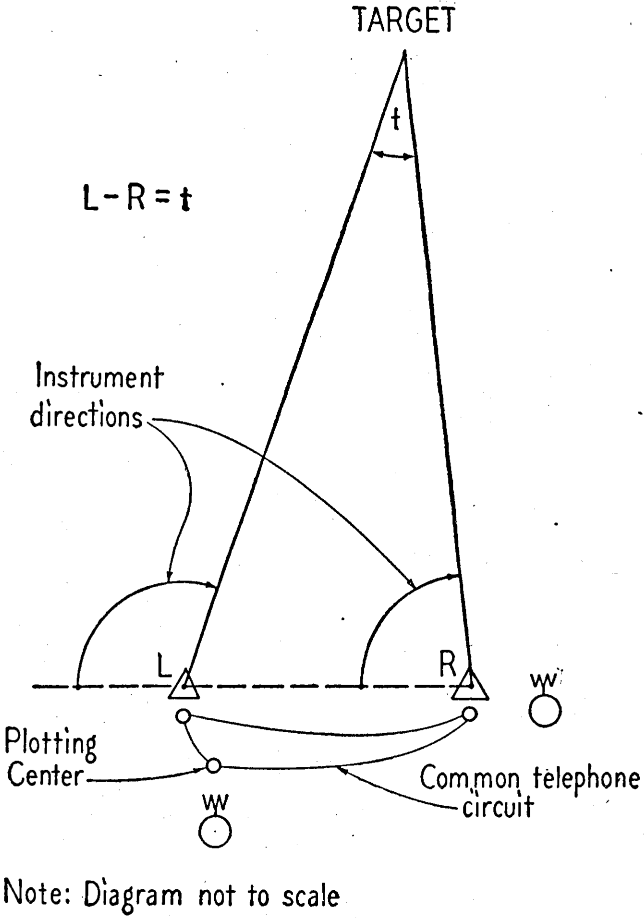
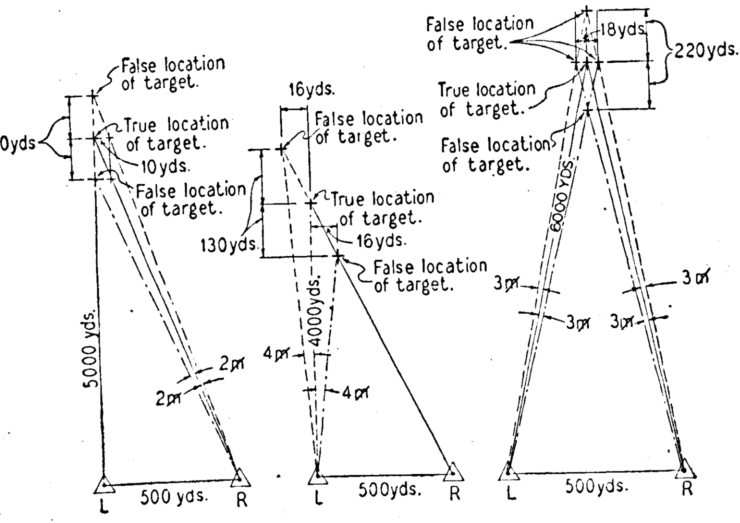


Figure 83. Short base flash ranging system.

where it is impossible to get more than one location that overlooks the enemy area.

(4) *Communication.* When the situation does not justify the laying and subsequent recovery of a large amount of wire.

b. Selection of observation posts. Both observation posts must afford observation throughout the same area in the assigned zone. Care must be taken during reconnaissance and occupation not to disclose their positions, and full advantage must be taken of camouflage and background. An observation post seen by the enemy usually is lost. Movement must be reduced to a minimum.



Note: Mil deviations shown indicate errors in instrument directions. Diagrams not to scale.

Figure 84. Target location errors due to incorrect instrument direction angles.

c. Intervisibility of observation posts. Installation and operation are simplified when observation posts are

intervisible; however, very little time should be spent in trying to achieve this situation.

d. Consideration of base length. The base length should be at least one-tenth of the estimated maximum range. Time available and unsuitable observation may dictate installation of a shorter base; however, immediate steps are taken to extend the length to a 1 to 10 ratio.

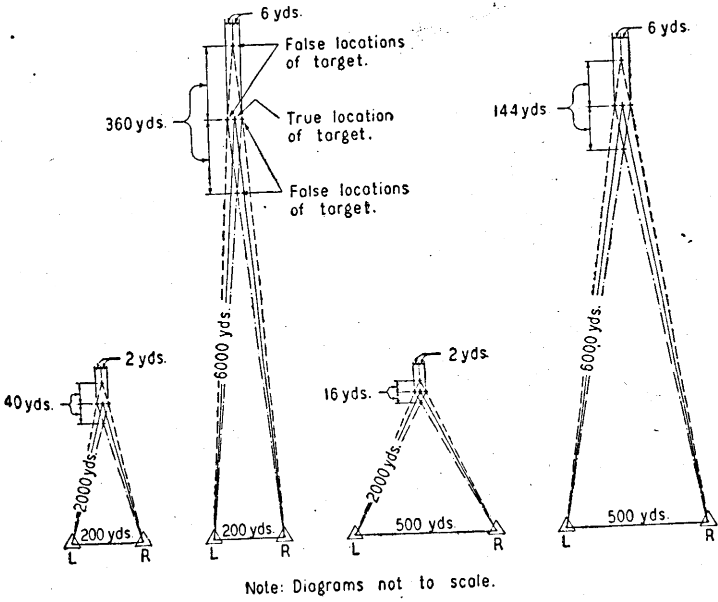


Figure 85. Target location errors due to 1-mil error in instrument direction angles; comparing various base lengths and ranges.

e. Orientation of base with respect to zone of observation. A short base is most effective when a line perpendicular to the center of the base passes through the center of the zone of observation. When this is not possible, a compensating increase should be made in the base length.

f. Accuracy of locations. Figures 84, 85, 86, and 87 illustrates the effects on the accuracy of target locations of errors in base length and particularly of errors in reading instrument directions.

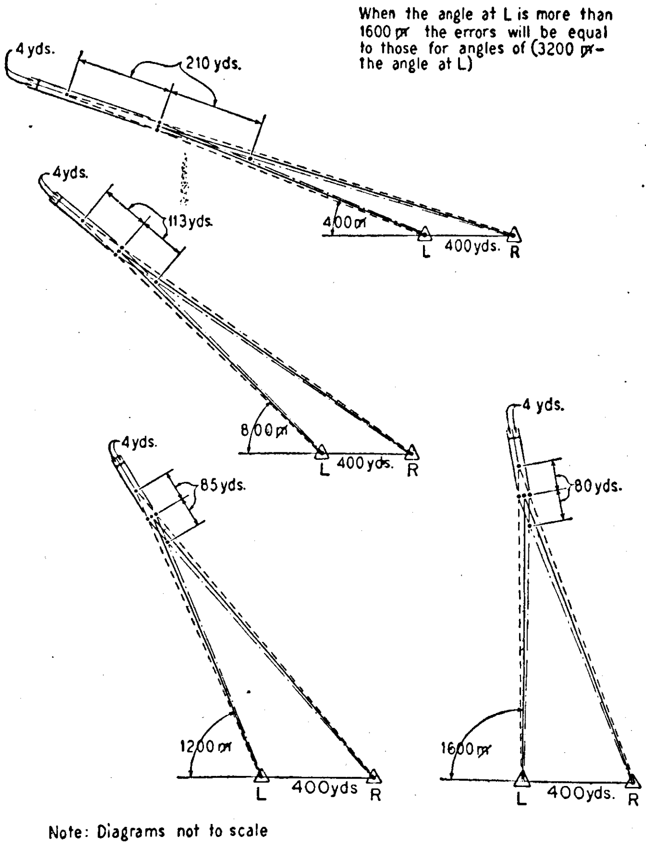


Figure 86. Increase in target location errors due to decreasing instrument direction angles, when base length, range, and error in instrument direction angles are constant.

g. Limitations. A short base is not as accurate as a long

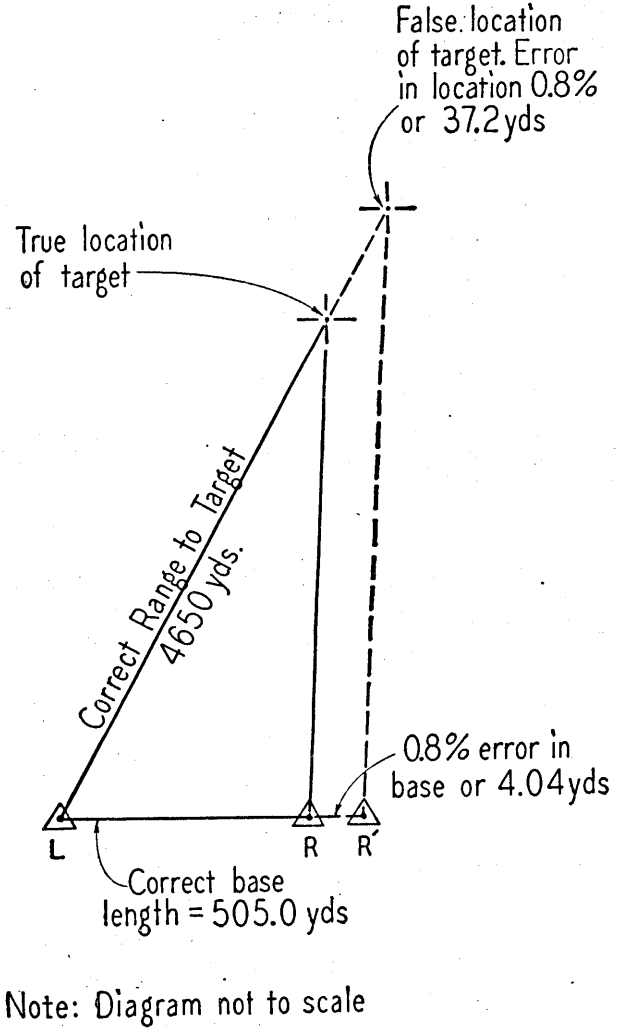


Figure 87. Error in range directly proportional to error in base.

base. Targets must have clearly defined features. A short base is not practical for night observations unless the actual flashes can be observed.

109. ORIENTATION OF INSTRUMENTS. a. Direct orientation. When the observation posts are intervisible, the observing instruments are oriented directly on each other.

(1) *Left observation post.* With 3,200 mils set on the instrument scale, sights on the center (sighting point) of the right observing instrument.

(2) *Right observation post.* With zero mils set on the instrument scale, sights on the center (sighting point) of the left observing instrument.

(3) *Both observation posts.* Upon completion of (1) and (2) above, both observers swing their instruments to the front. The observers are then ready to observe and report.

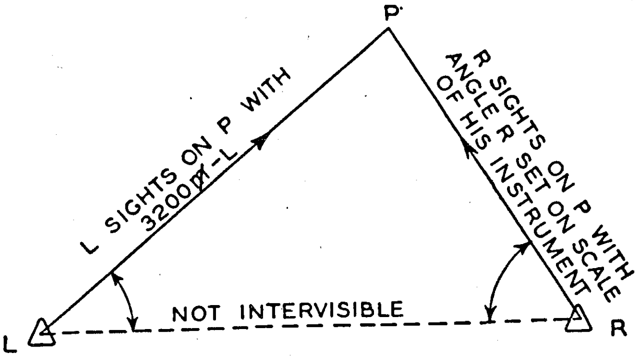
b. Indirect orientation. When the observation posts are not intervisible, the observing instruments must be oriented on an auxiliary point, either to the front or to the rear of the base. During the computation of the base length, the two interior angles (angle *L* and angle *R*) are determined. (See fig. 88.)

(1) *Orienting point to front of base.* (*a*) *Left observation post.* Sights on the orienting point with 3,200 mils minus angle *L* set on the scale of his instrument.

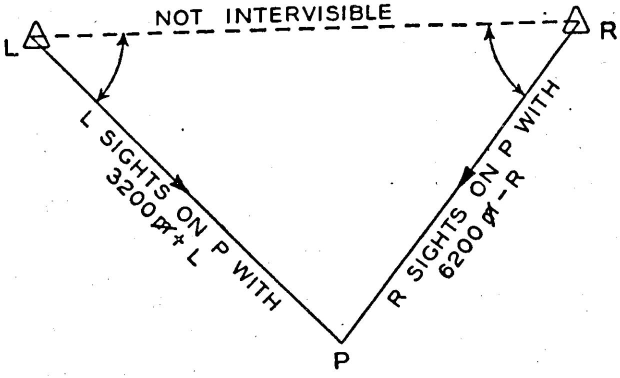
(*b*) *Right observation post.* Sights on the orienting point with angle *R* set on the scale of his instrument.

(2) *Orienting point to rear of base.* (*a*) *Left observation post.* Sights on the orienting point with 3,200 mils plus angle *L* set on the scale of his instrument.

(*b*) *Right observation post.* Sights on orienting point with 6,400 mils minus angle *R* set on the scales of his instrument.



a. ORIENTING POINT TO FRONT



b. ORIENTING POINT TO REAR

Figure 88. Indirect orientation.

(3) *Both observation posts, orienting point to front or to rear of base.* Upon completion of the steps above, both observers swing their instruments to the front. The observers are then ready to observe. (A stake is established at least 100 yards distant from each observation post for night orientation.)

110. SURVEY METHODS. a. General. The internal survey of a flash short base consists of two operations: (1) determination of the base length, and (2) determination of orientation angles for the observing instruments.

b. Accuracy required. (1) *Orientation of instruments.* Since a very small error in orientation will produce large errors in ranges, the observing instruments are oriented as carefully as possible.

(2) *Measurement of the base length.* Since the error in range is proportional to the error in base length, the base should be determined to a degree of accuracy not less than 1 in 500. Distances should be double-taped habitually as a check against errors.

c. Measurement of base length. (1) *Selection of survey method.* The selection of the method used for determining the base length depends upon the intervisibility of the observation posts and upon the accessibility of the intervening terrain. Accessibility of the terrain depends not only on the topography but also on possible exposure of personnel to the enemy. Thorough reconnaissance to determine these factors is necessary before a survey method is selected. Alternate survey methods are illustrated and described in figures 89 through 96. In using methods involving auxiliary bases, consideration must be given to the strength of figure. Avoid use of angles of less than 300 mils. (See par. 52.)

(2) *Direct taping method.* When the observation posts

are intervisible and the intervening terrain is accessible for taping, the base length may be taped directly. Direct orientation is used. In figure 89, measure distance *LR*.

(3) *Cotangent relation method* (fig. 90). When the observation posts are intervisible but the intervening terrain is inaccessible, an auxiliary short base may be taped at right angles to the base from either observation post (side *LA*).

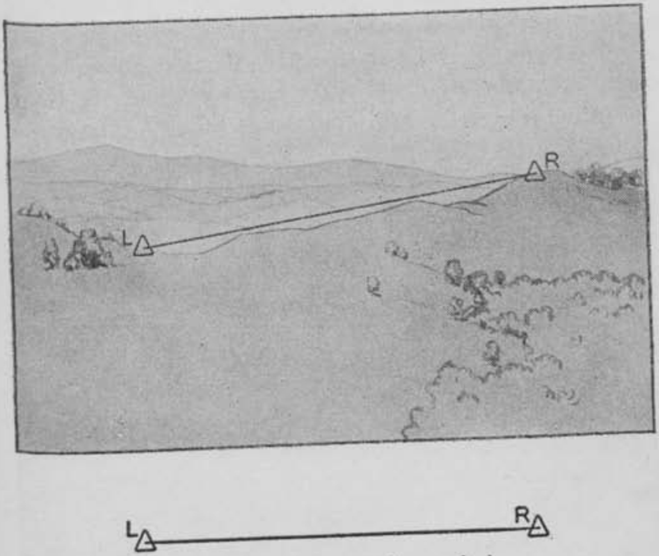


Figure 89. Direct taping method.

The angle *LRA* is measured at the observation post opposite the auxiliary short base. The base length is determined by the formula: $LR = LA \cot R$.

(4) *Sine law relation method* (fig. 91). When the observation posts are intervisible but the intervening terrain is inaccessible and the terrain precludes the use of an auxiliary base at right angles to the base from either observation post, an auxiliary short base may be taped at any angle to the base from either observation post (side *LA*). The left ob-

server measures the angle *RLA* and the right observer measures angle *LRA*. Angle *LAR* is computed as:

$$\angle A = 3{,}200 - (\angle L + \angle R)$$

The base length is determined by the formula:

$$LR = \frac{LA \sin A}{\sin R}$$

Direct orientation is used.

(5) *Point "P" method* (fig. 92). When the observation posts are not intervisible but the terrain to either the front or to the rear of the base is accessible for taping from the

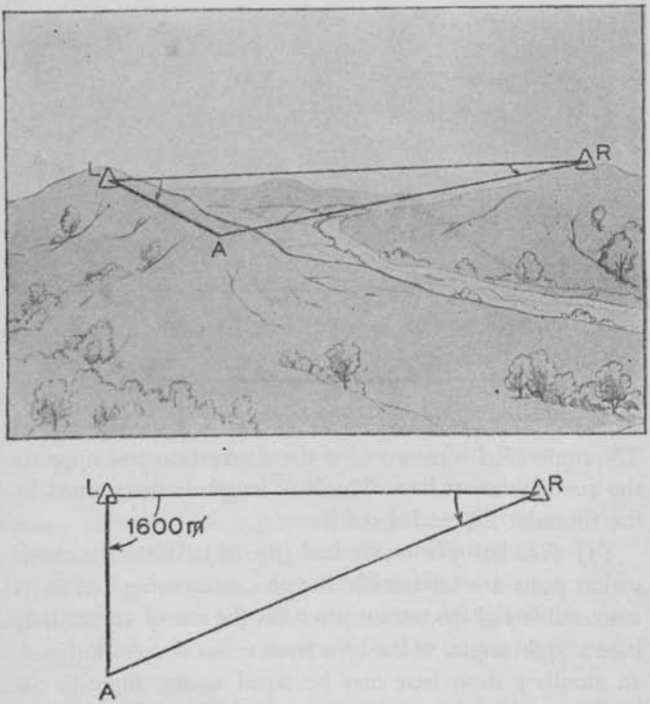
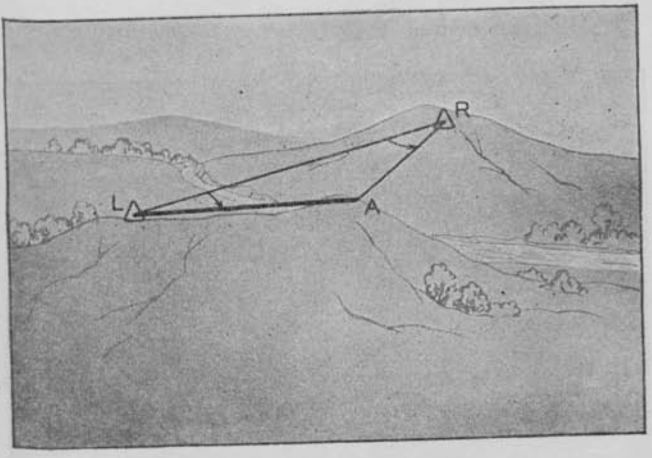


Figure 90. Cotangent relation method.

observation posts, a point P, visible from both observation posts, may be selected to the front or rear, and the distances from the point P to each observation post are taped.



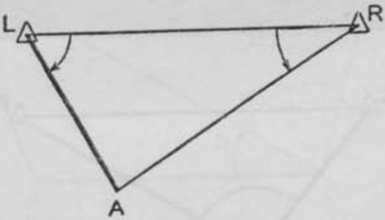


Figure 91. Sine law relation method.

The angle LPR is measured and the base length LR is determined in two steps, by the formulae:

(a) $\tan L = \dfrac{PR \sin P}{PL - PR \cos P}$

(b) $LR \equiv \dfrac{PR \sin P}{\sin L}$

(c) $\angle R = 3{,}200 - (\angle L + \angle P)$

If the angle at P is greater than 1,600 mils, it must be borne in mind that cos P is negative. When PR cos P is positive and greater than PL, tan L is negative and L is greater than 1,600 mils.

Indirect orientation is used.

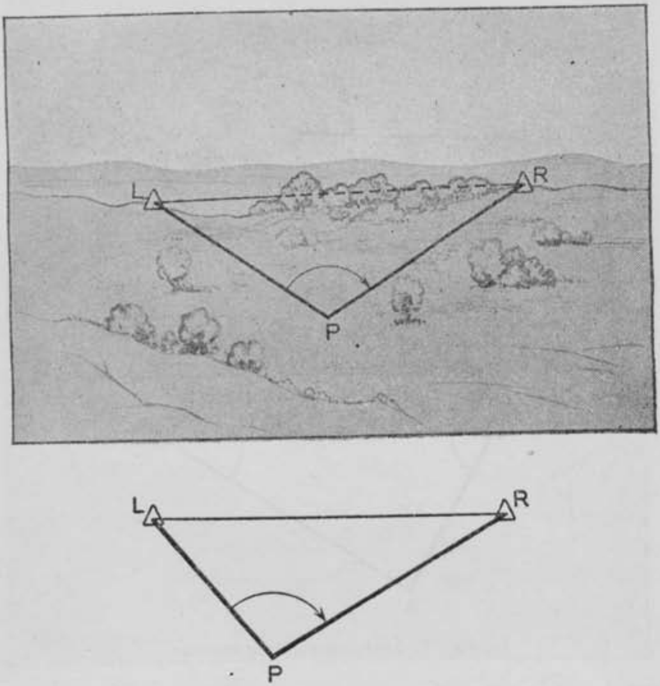


Figure 92. Point P method.

(6) *Triangulation methods.* A method of triangulation may be used when the terrain between the observation posts is not accessible for taping and the terrain either to the front or to the rear of the base is not accessible for use of other methods described above, but the terrain to either the front or to the rear is accessible for establishing, by direct taping,

an auxiliary base, both ends of which are visible from both observation posts.

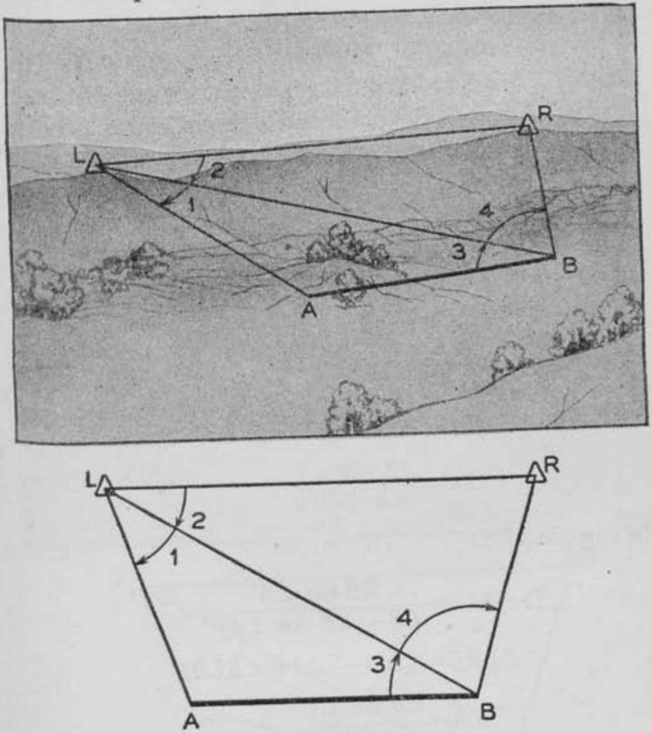


Figure 93. Triangulation, intervisible observation posts.

(*a*) *Intervisible observation posts* (fig. 93). The length of the auxiliary base *AB* is taped and the angles 1 and 2 at point *L* and angles 3 and 4 at point *B* are measured. The base length is determined by the formulae:

$$\angle A = 3{,}200 - (\angle 1 + \angle 3)$$

$$\angle R = 3{,}200 - (\angle 2 + \angle 4)$$

$$LB = \frac{AB \sin A}{\sin \angle 1}$$

$$LR=\frac{LB \sin \angle 4}{\sin R}$$

Direct orientation is used.

(*b*) *Nonintervisible observation posts* (fig. 94). The distance *AB* is taped and the angles 1 and 2 are measured at point *A*, and the angles 3 and 4 are measured at point *B*. The base length is determined by solving successive triangles.

In triangle *LAB:*

$$\angle BLA=3{,}200-(\angle 1+\angle 2+\angle 3)$$

$$LB=\frac{AB \sin (\angle 1+\angle 2)}{\sin BLA}$$

In triangle *RAB:*

$$\angle ARB=3{,}200-(\angle 2+\angle 3+\angle 4)$$

$$RB=\frac{AB \sin \angle 2}{\sin ARB}$$

In triangle *LBR:*

$$\text{Tan } RLB=\frac{RB \sin \angle 4}{LB-(RB \cos \angle 4)}$$

$$\angle LRB=3{,}200-(\angle 4+\angle RLB)$$

$$LR=\frac{RB \sin \angle 4}{\sin RLB}$$

Indirect orientation on point *B* is used.

(7) *Two-point resection method* (fig. 95). When the observation posts are intervisible and conditions exist as described in (6) (*a*) above, a two-point resection may be performed to determine the base length. An auxiliary base *AB* is established as for a solution by triangulation. Distance *AB* is taped and angles 1, 2, 3, and 4 are measured. An arbitrary base length *LR* is assumed and a corresponding auxiliary base length *AB* is computed by the method

in (6) (*b*) above. The true base length *LR* is determined by the proportion

$$\frac{LR\text{ (true)}}{LR\text{ (assumed)}} = \frac{AB\text{ (true)}}{AB\text{ (assumed)}}$$

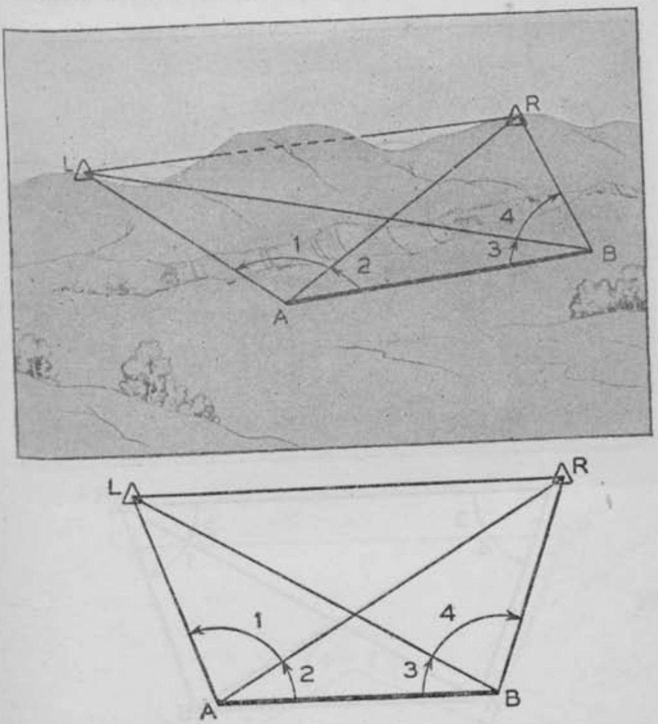


Figure 94. Triangulation, nonintervisible observation posts.

Direct orientation is used. This method has the advantage that observing instruments need be set up only at observation posts.

(8) *Traverse method* (fig. 96). When the observation posts are not intervisible and none of the previously described methods of survey are applicable, it will be neces-

sary to run a traverse from one observation post to the other, and compute the base length. Assume coordinates for one observation post and an azimuth to station 1 on the traverse. Upon completion of the traverse, compute the coordinates of the other observation post and the distance

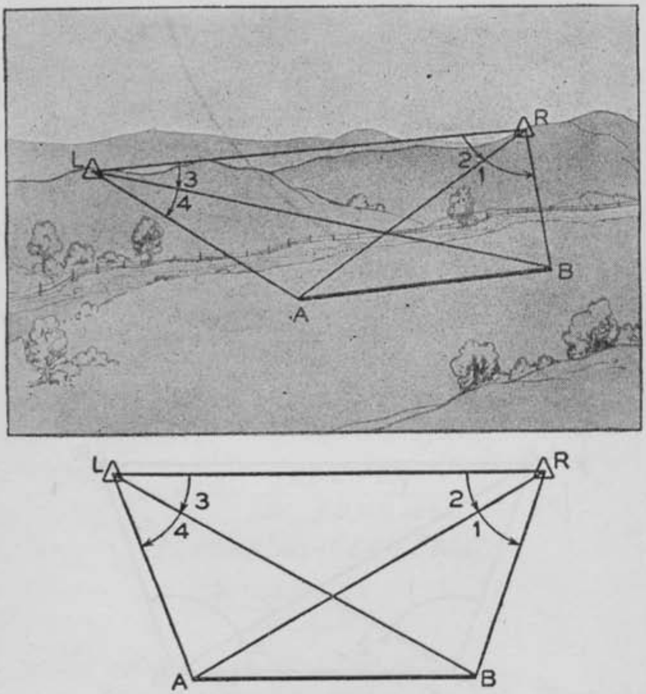


Figure 95. Two-point resection method.

and azimuth of the base (*LR*). (See par. 49.) Compute the angles at each observation post between the base and the next adjacent leg of the traverse by determining the differences in the respective azimuths. Indirect orientation is used. Each observation post is oriented on the next adjacent traverse station.

d. Survey control. The short base survey is connected to the fire direction survey or other established control as soon as practicable. It can be accomplished by—

(1) Traverse, triangulation, resection, or a combination of these. This should replace any other method as soon as possible.

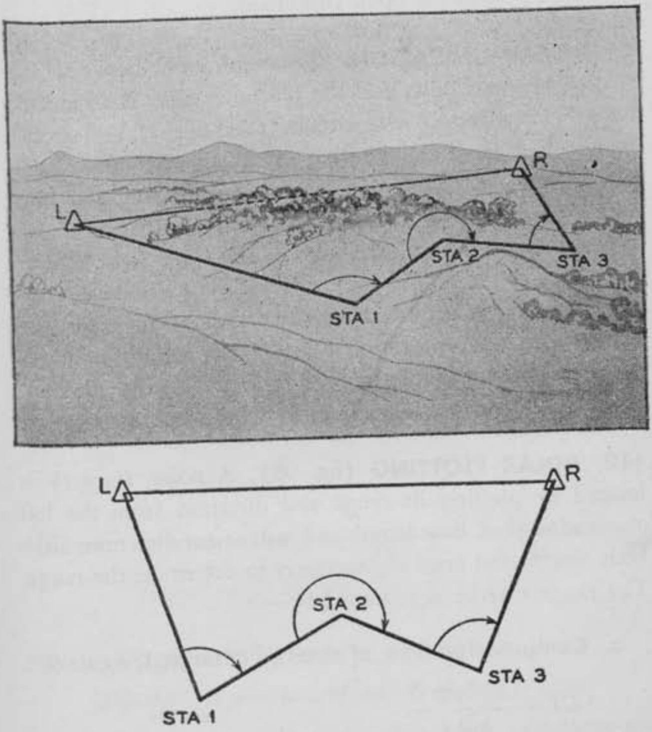


Figure 96. Traverse method.

(2) Inspection or short traverse from some identifiable feature on an accurate large-scale map or air photo.

(3) Any graphical solution.

(4) Compass direction and location (coordinates) of the base or check point.

(5) Firing. An adjustment is fired and an adjusted compass determined. The observation post is located with respect to the point on which the adjustment was fired by determining the compass direction and range from the observation post to the point concerned.

111. COMMUNICATION. Communication between the two observation posts and the plotting center is conducted by a "closed loop" wire circuit. (See fig. 83.) A circuit is first laid from the plotting center to each observation post. Later the observation posts are interconnected by a wire circuit, thereby completing the loop so that communication may be maintained between the three stations even if one leg of the loop is broken. Each short base flash ranging team is also equipped with two radios which are used initially for communication between the most distant observation post and plotting central, and as an alternate means of communication after the wire circuit is installed.

112. POLAR PLOTTING (fig. 99). A point (target) is located by plotting its range and direction from the left observation post. Base length and instrument directions from both observation posts are necessary to determine the range. The range may be determined by—

a. Computation (law of sines). For target 1, figure 97:

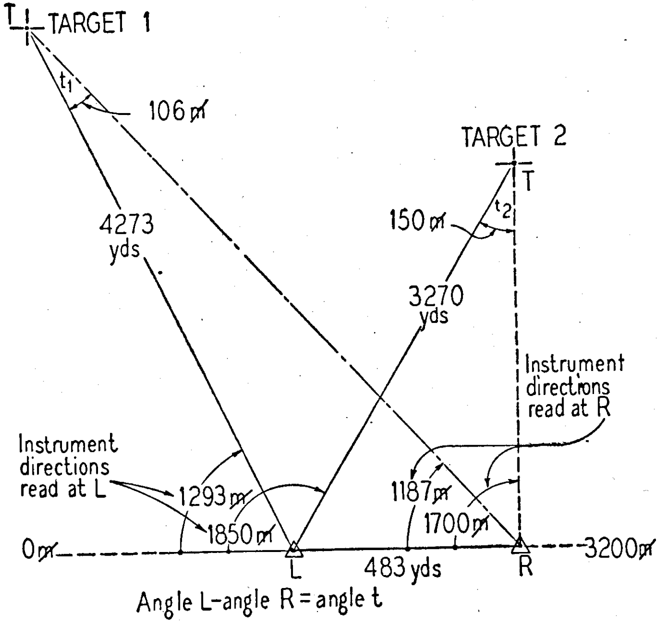
$$LT = \frac{LR \times \sin R}{\sin t}$$

$$LT = \frac{483 \times \sin 1187_m}{\sin 106_m}$$

$$\begin{aligned} &\log 483 &&= 2.68395 \\ &\log \sin 1187_m &&= 9.96328 - 10 \\ &\log \sin 106_m &&= 9.01652 - 10 \end{aligned}$$

log range	=3.63071
Range	=4273 yards

b. Military slide rule. The military slide rule is designed to simplify and speed up the solution of the oblique triangle. This slide rule is a special type Mannheim slide



Note: Diagram not to scale

Figure 97. A short base, instrument readings to target.

rule and can be used in performing many arithmetic and trigonometric calculations in the same manner as standard commercial slide rules. It is used primarily in the solution of military survey. Short base problems and computations of coordinates from distance and bearing are quickly solved by means of the rule. (See TM 9–524.)

Accuracy of rule = 1/1000 under optimum conditions.

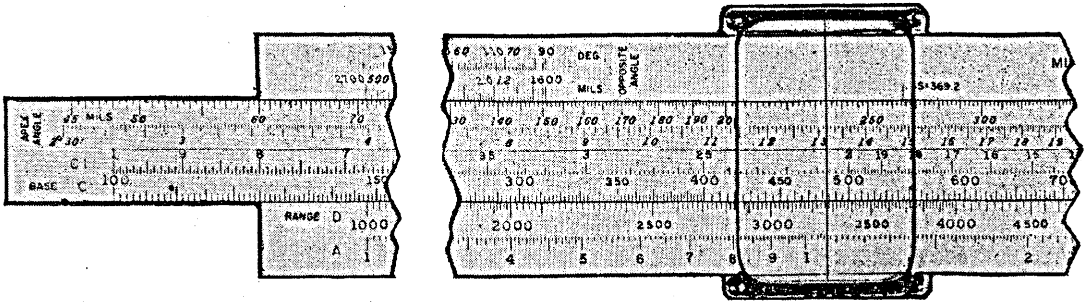


Figure 98. Solution for target 2 in figure 97, using the military slide rule.

Example (fig. 98.):

Under 1700 on the OPPOSITE ANGLE SCALE, set 150 on the APEX ANGLE SCALE; then move the hairline to 483 on the BASE SCALE; under the hairline, read 3,270 yards on the RANGE SCALE.

c. Plotting. See figure 99 for method of polar plotting.

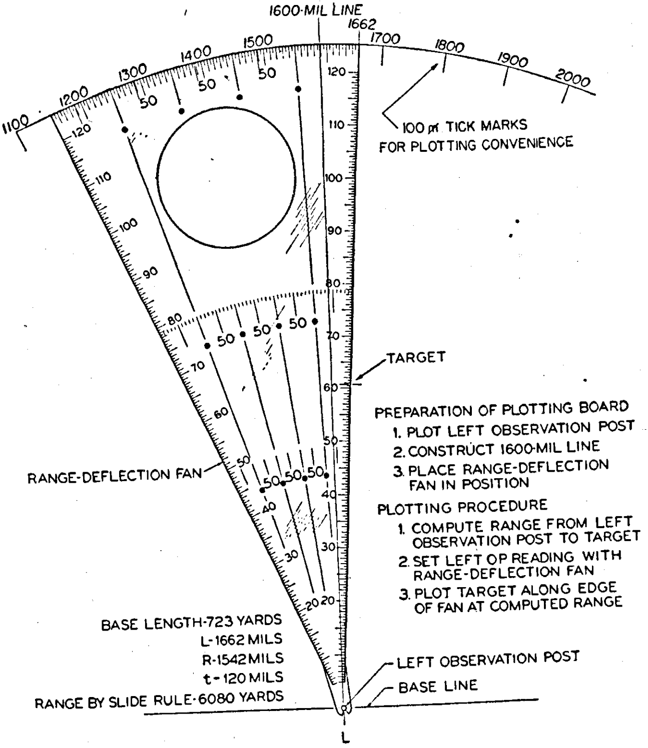


Figure 99. Polar plotting.

113. FORTY-FIVE DEGREE PLOTTING. The 45° method is a graphical method of plotting locations when using the

short base. It always insures that the two rays will intersect at 45° (at the target), thus giving a stronger intersection than would be obtained by plotting directly the rays from the left and right observation posts.

a. Preparation for plotting. (1) The *t*-angle scale corresponding to the base length is selected (fig. 100) and a fine pencil line is drawn the full length of the scale strip between the proper base length graduations.

(2) The plotting sheet is prepared as indicated in figure 101.

b. Plotting. The range-deflection fan is pivoted over *L* and rotated until its right edge is at the angle reported by the observer at *L*. The 45° guide is then moved along the right edge of the fan until one of its parallel sides intersects the fine pencil line on the *t*-angle scale at the intersection (*P*) of the line representing the appropriate *t*-angle. The intersection of this parallel side of the guide with the right edge of the fan is the target and may be marked with a pencil or pin. (See fig. 101.)

c. Plotting at scales other than scale at which t-angle strip is constructed. (1) The *t*-angle scale is multiplied by the ratio $\left(\frac{RF \text{ of chart}}{\text{Scale of } t\text{-angle scale}}\right)$ or a *t*-angle scale to the scale of the chart may be constructed.

(2) Steps for the preparation of the plotting sheet are as indicated in figure 101. All base length measurements on the chart are made to the scale of the chart. Registration lines are constructed perpendicular to each other as indicated in figure 101. For plotting convenience, one of the lines is drawn 1.8 inches from *R*, regardless of the scale of the chart.

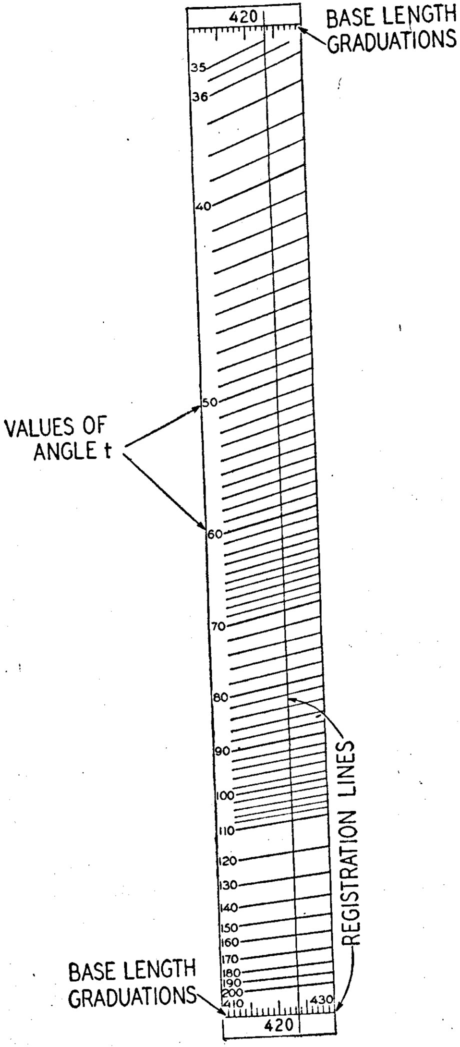


Figure 100. A t-angle strip (with pencil registration line drawn for a base length of 423.5 yards).

d. Capabilities and limitations. Forty-five degree plotting affords a rapid, accurate means of plotting by one man, particularly on odd-scale plotting charts. Great care

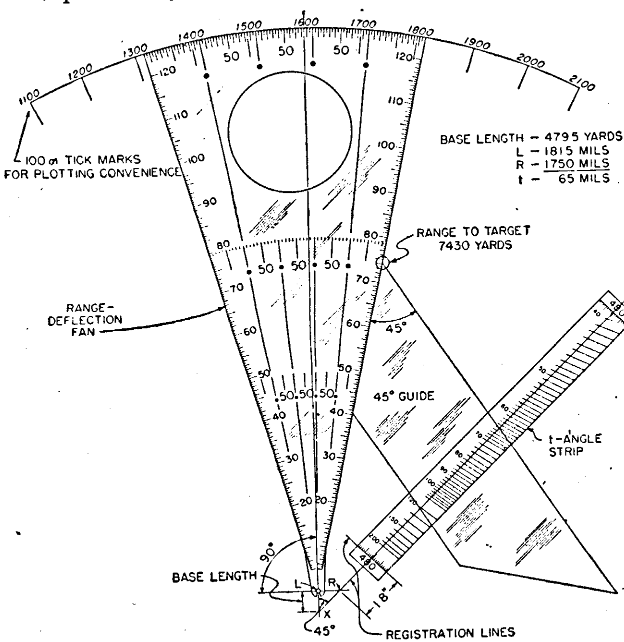


Figure 101. 45° plotting.

must be exercised initially in setting up the plotting equipment on the chart. The *t*-angle scales are usually made up for bases up to 600 yards. For longer bases, rays are plotted from *R* and *L*, directly, the intersection locating the target.

114. CONSTRUCTING T-ANGLE SCALE. To construct a *t*-angle scale for any particular base length, solve the following equation for various values of *t* and lay off the distances *RP* from the point *R:*

$RP = 0.707\ b\ (\cot t{-}1)$

where b = base length

t = vertex angle

RP = distance from R to graduation corresponding to t. (See fig. 101.)

Similarly, a set of t-angle scales may be constructed. Lay off on a large sheet of paper a scale of base lengths at some convenient scale, approximately 1 inch = 20 yards, from 0 to 600 yards along a base line. (See fig. 102.) Erect a perpendicular to the base line at the 600-yard base length graduation. Compute the value of RP for t-angles from 50 to 300 mils for a base length of 600 yards. Lay off these values along the perpendicular through the 600-yard graduation at the scale at which it is desired to plot. Connect these points (P) by straight lines with the 0 point on the base. These are the t-angle lines and may be used for any base length. As a convenience in plotting, a registration line (1.8 inch) is laid off parallel to the base line below which the t-angle lines are not drawn. The portion of the sheet below the registration line is cut off. Label the t-angle graduations and cut the sheet into strips. The strips are now ready for use and will provide locations of targets directly at the scale for which drawn when the base LR is laid off to the same scale. The t-angle strip for base lengths from 440 to 460 yards is shown in figure 102.

115. TYPES OF PLOTTING CHARTS AND METHODS OF REPORTING TARGETS. The type of plotting chart used depends upon the survey by which the flash short base is tied to the firing chart of the supported unit. Plotting may be performed by either polar or 45° plotting. The method of reporting targets depends upon the type of plotting chart used.

a. Grid Sheet. A grid sheet may be used when the flash base and the supported unit are connected by common survey and when the supported unit is using a grid sheet as a firing chart, in the absence of a suitable map or air photo. Targets are usually reported by rectangular coordinates and fire is conducted by *forward observer methods.*

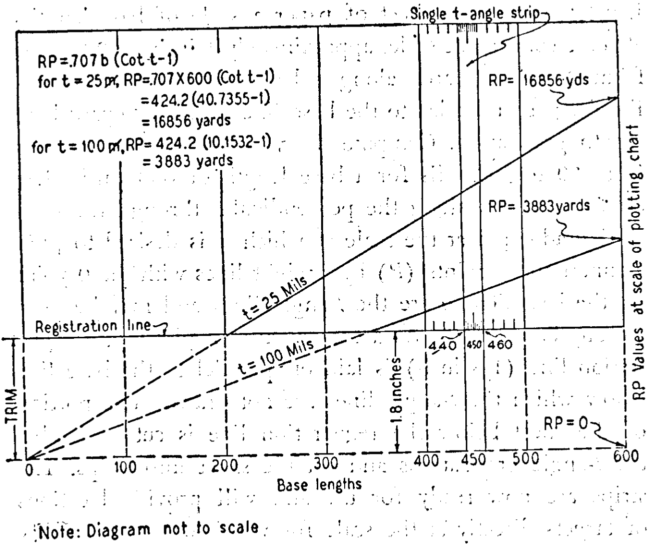


Figure 102. Construction of t-*angle scales.*

b. Battle maps and (air) photos. When either a battle map or air photo is being used as a firing chart by the supported unit, flash units may also plot their short base on a similar map or photo, and plot locations by any of the methods described above, directly on the map or photo.

c. Transparent grid. If the supported unit is using a grid sheet as a firing chart, the flash unit may superimpose this transparent grid on their plotting board, and locate and report targets on this grid. (See fig. 103.) The

position of the base point is obtained by the method described in f below.

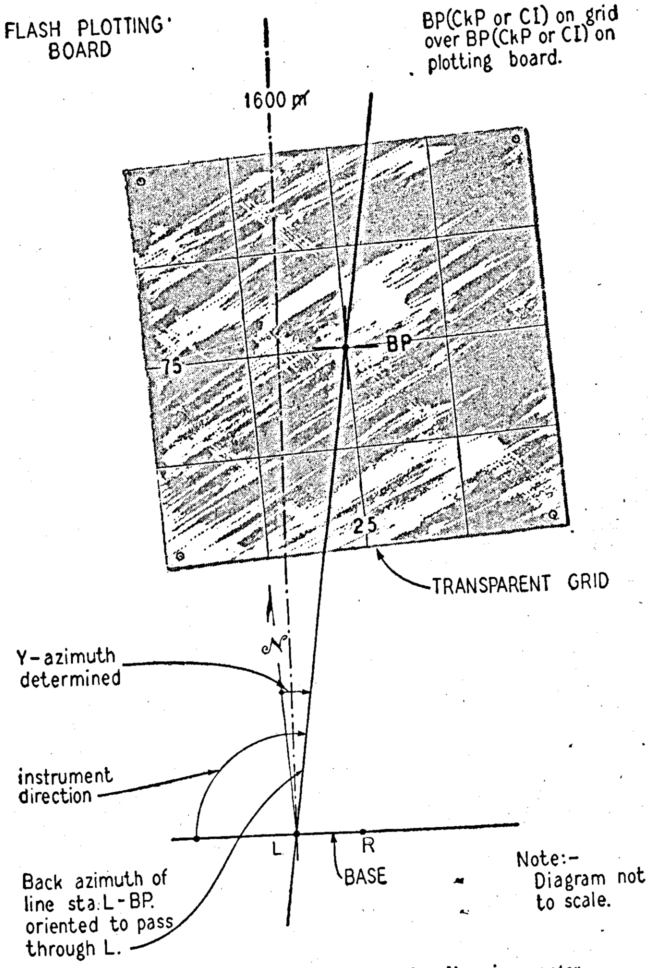


Figure 103. Reporting targets to fire-direction center, transparent grid.

d. Range and instrument direction. Targets may be located and reported by computed range and the direction from one observation post, as shown in figure 104. (See f below for method of relating the flash plotting chart to the plotting chart being used by the firing unit.)

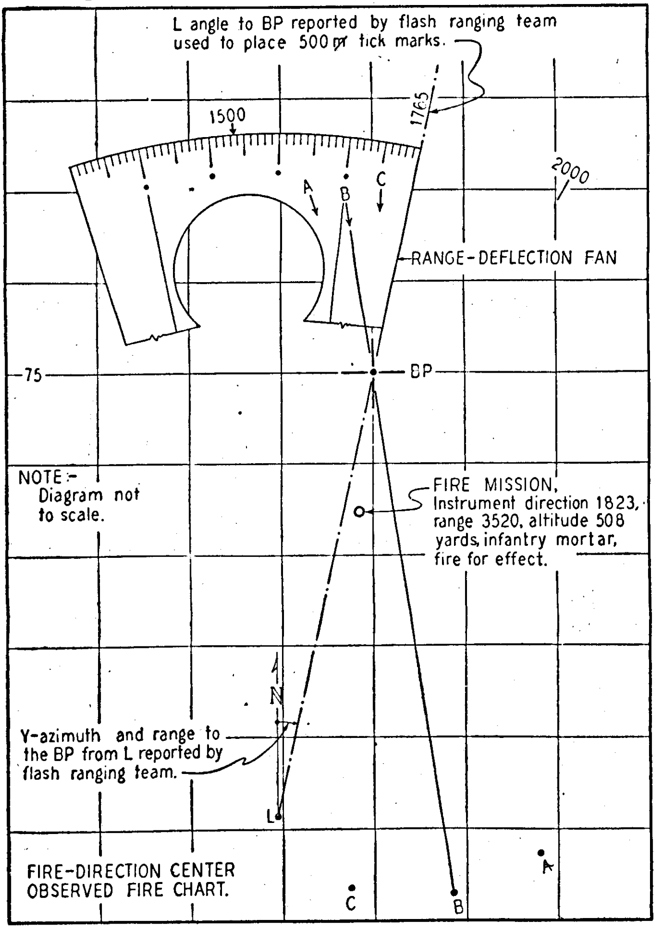


Figure 104. Reporting targets to fire-direction center by polar coordinates.

e. Forward observer methods. Forward observer methods are used in reporting targets when no common grid exists. See f below for method of preparing plotting chart for reporting in this manner. Forward observer methods are described in FM 6–40.

f. Marking base point. Regardless of the type plotting chart used, the flash unit may register by asking the firing unit to mark base (check) point. *Example:* Mark base point, Smoke, Two rounds. The base point is plotted on the chart as the center of impact of these rounds. The firing unit furnishes the range and direction to base point. The adjusting piece is back plotted on the chart from the base point. Thereafter, gun-base point or gun-target line can be quickly produced on the flash plotting chart.

If the flash unit and firing unit are not on a common grid, the short base may be located and oriented with respect to the base point and base line in the following manner:

(1) Plot marked base point by any short base method.

(2) Determine direction (azimuth) from left observation post to base point, and draw a line through these two points on the plotting chart.

(3) Determine angle at the base point from difference of directions (azimuth) of the gun-base point line and left observation post-base point line.

(4) Lay off this angle at the base point by protractor in the proper direction from the left observation post-base point line.

(5) Back plot adjusting piece at the correct range from base point on this line. If the piece falls off the plotting chart, an auxiliary chart may be used to obtain this position.

Example: See figure 105.

116. OPERATING PROCEDURE. a. Installation. Rapid flash ranging installations will often be made by a minimum number of personnel and no fixed procedure for installation is prescribed. The observation posts are selected by the flash officer, with the assistance of the sergeant observer, in accordance with the considerations specified

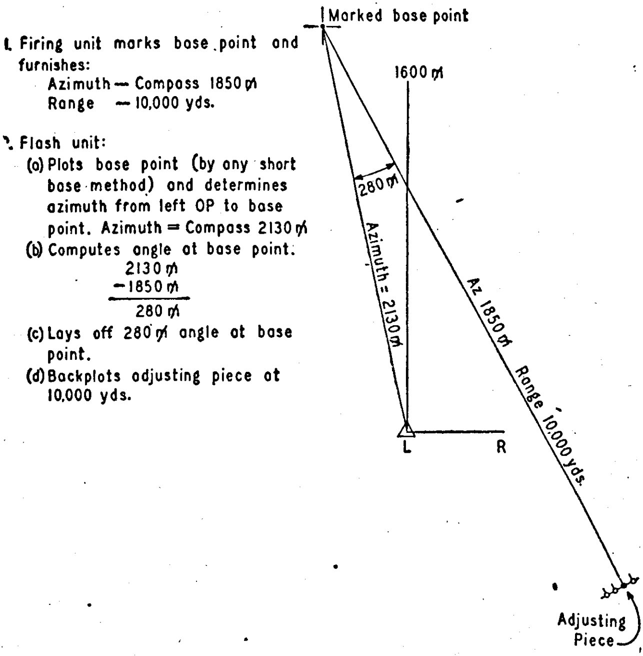


Figure 105. Orientation and location of short base with respect to base point.

in paragraph 108. Survey of the base is performed and communication between plotting center and observation posts established by the members of the team under the direction of the flash officer and sergeant observer. The plotting chart is prepared as soon as survey of the base,

computation of the base length, and orientation are completed. The observation posts are furnished the data with which to orient their instruments when indirect orientation is used. For method of checking orientation by astronomic observations, see paragraph 120.

b. Observer procedure. (1) Upon occupation of their posts, observers set up observing instruments and commence a methodical and careful search of the target area, whether or not survey and communication are complete, making pertinent notes regarding targets, check points, etc. *A panoramic sketch should be prepared.* (See fig. 106.) Readings to targets may be made before orientation is possible by zeroing the instruments on one or more selected reference points. A complete target area survey is begun by locating all important terrain features, such as crossroads, hills, buildings, clumps of trees, etc. In short, observers undertake immediately to *index* the terrain.

(2) As soon as the observation posts are occupied, the observers identify reference points to each other. These should be distributed both in range and direction. Computed ranges to these reference points should be memorized and noted on panoramic sketches, as guides in estimating target ranges. When a target is discovered by one observer only, he reads the instrument direction and, using the estimated range, applies the estimated t-angle (using mil relation) to provide the approximate instrument direction for the other observation post. The results are then reported. *Example:* Enemy tanks assembling, 1350, Range 6000. If there is any question regarding the proper identification, the observer should attempt immediately to identify the target by all additional means. Panoramic sketches are essential observation post records and aid in identification of targets.

(3) In an emergency, observers may have to resort to the *flash bang* method, where the target is visible only

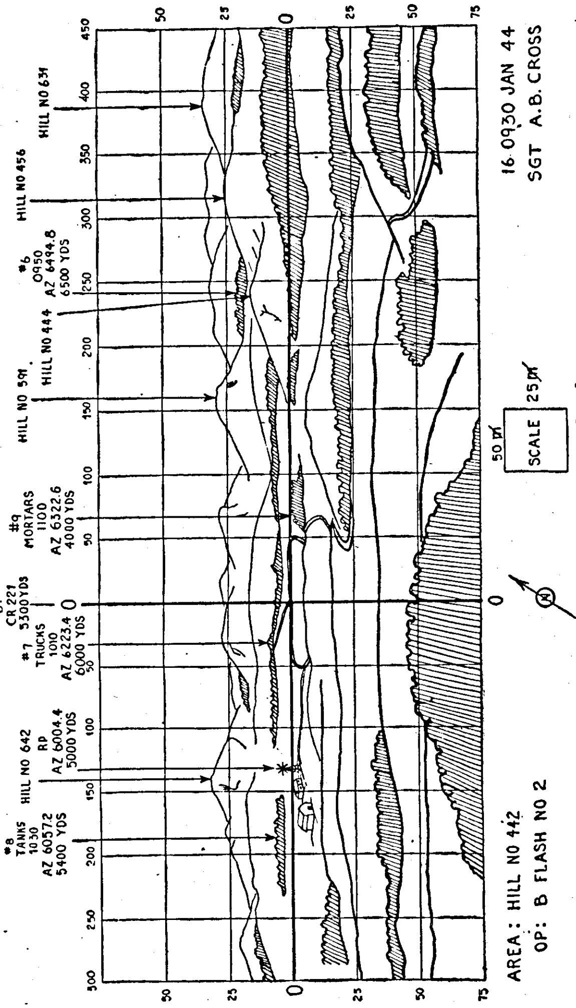


Figure 106. Panoramic sketch.

to one observation post. In addition to obtaining the direction to the gun, the observer measures the (time) interval between the time he sees the flash and the time he hears

the sound. He is equipped with a stop watch for this purpose. The time interval is a measure of the range to the gun.

(4) Location can also be made from a single observation post by observing the direction and angle of site to a target. The ray is drawn on a map. A profile section along this line is made and the line of site is drawn. The intersection of this line with the ground, with due consideration to curvature and refraction, will give the range to the enemy gun. Direction and range to the target are determined and reported. *Where targets are visible to single observation posts, observers must be prepared to assume the role of a forward observer to adjust fire on the target* (*FM 6–40*).

(5) When observing on a moving target, the observers track the target until the directing observer indicates the instant to stop tracking and read. A prearranged count should be used. *Example:* Left OP: "Track moving gun"; Right OP: "On"; Left OP: "1-2-3-mark." Both instruments are read and reported to plotting center in turn.

c. Flash ranging location. The instant a target is sighted by either observer, he reports "Flash," and when it is sighted by the other observer, he reports "On." The computer (draftsman) then commands "Left (right) OP, report." In response, the left (right) observer reports instrument reading, accuracy of reading, and site to the target; for example, "1895.6, Able, Si minus 3, Enemy gun firing." Observers qualify all readings as Able, Baker, or Charlie, according to the following standard of accuracies:

Able —reading accurate.

Baker —reading in error less than 2 mils.

Charlie—reading in error greater than 2 mils.

Note.—For short base locations, only Able readings are of value in plotting. Baker and Charlie readings are too inaccurate for a location, but indicate that the observer is on the target and should be able to report an Able reading on the next observation.

The computer (draftsman) records this information and calls for a report from the other observer, who reports in a like manner. The computer (draftsman) plots the location of the target, recording range, coordinates (if applicable), and altitude. (Altitude is corrected for curvature and refraction for ranges over 5,000 yards, sec. IX, ch. 9.)

117. ADJUSTMENT AND TRANSFER OF FIRE. Transfer limits and the selection of check points for registration are governed by the same considerations as apply in gunnery. (See FM 6–40.) Surprise fire may be placed on any targets within transfer limits since accurate locations of targets are made by the short base team. Transfers may be made from appropriate centers of impact or high burst mean-point-of-burst, from base points, check points, reference points, or from previous targets and concentrations upon which fire has been delivered. Adjustments are described in paragraph 127.

118. ALTERNATE OBSERVATION POSTS. Continuous reconnaissance must be conducted to locate the best observation posts and alternate observation posts. These new observation posts should be surveyed, by taking advantage of the base in operation, and made ready for occupancy and change-over with a minimum of interruption.

Section III. DELIBERATE INSTALLATIONS

119. GENERAL. When all observation posts are located and oriented on a common grid and communication is appropriate to the situation, a deliberate installation exists.

Locations of targets and points in the target area are then determined by plotting the *Y*-azimuth to the target from each observation post. A typical installation is shown diagrammatically in figure 107.

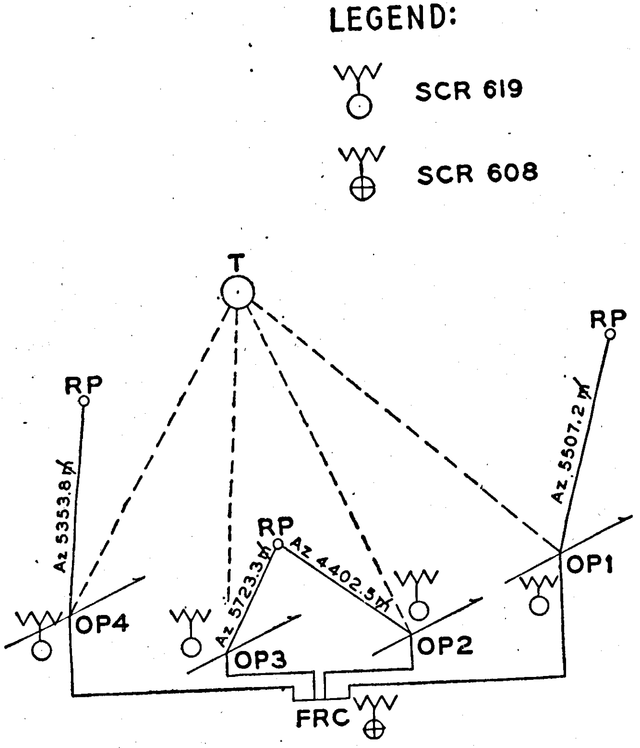


Figure 107. Flash ranging diagram, four observation posts.

a. General considerations. An accurately surveyed flash ranging installation with multiple observation posts is employed to secure maximum accuracy and reliability of locations, whenever conditions permit. The necessary conditions are—

(1) *Adequate time for installation.* Time must be adequate to allow completion of accurate survey of the observation posts and installation of the necessary communication facilities.

(2) *Survey control.* Common survey control should be available to permit accurate survey of all observation posts on the existing grid system.

(3) *Suitable terrain.* The terrain should afford multiple vantage points, overlooking the enemy area, for siting the observation posts. In order to obtain the maximum number of intersecting rays on targets, all observation posts must be able to observe in the same enemy area. Intervals between adjacent observation posts should be not less than one-tenth of the maximum range limit of the target area.

(4) *Communication.* The flash ranging central (FRC) and observation posts may initially be connected by radio but wire is installed as soon as practicable. Each observation post normally is connected to the flash ranging central by a single wire line with radio as an alternate means of communication. (See fig. 107.)

(*a*) *Flash switchboard.* All wire circuits from the observation posts to the flash ranging central terminate at the switchboard. (See fig. 108.) The flash switchboard is a specially designed switchboard which, in addition to normal switchboard equipment, has means to indicate by a visual as well as audible signal the instant that a target has been sighted by the observers. When the signals from all observation posts occur at the same instant, the switchboard operator can assume with reasonable accuracy that all observation posts have sighted the same target.

(*b*) *Observation post equipment.* Each observation post is equipped with an observing instrument, an outpost set, a map, compass, and a stop watch. Various types of observing instruments may be in use. However, all should be designed to measure horizontal and vertical angles. The

outpost set is used to provide the observer with a remote control unit to activate the signal on the switchboard the instant a target is sighted, and with communication to the flash ranging central. An oriented map or panoramic sketch will aid the observer in identification and location of targets.

Figure 108. The flash switchboard.

b. Orientation of base with respect to target area. Observation posts may be in irregular alignment or spaced at fairly regular intervals, depending upon the terrain. The ideal installation will permit the perpendicular bisector of a line connecting the two extreme observation posts to pass near the center of the target area.

c. Numbering of observation posts. Observation posts are numbered consecutively from right to left facing the front. (See fig. 107.)

d. Advantages and disadvantages. (1) A deliberate flash ranging installation affords greater accuracy and reliability of target locations than a short base because of the multiple rays that can be constructed through any one target and the larger angles of intersection. Locations are made on a grid system and reported by coordinates. Control of all observation posts is centralized at the flash central, thus providing for maximum coordination of flash observation facilities.

(2) Considerably more time, survey, and wire are necessary for the complete installation of a long flash base than for a short flash base. The terrain must be suitable for this type of installation.

120. ORIENTATION OF INSTRUMENTS. Each observing instrument must be oriented so that the zero on the scale is on grid or prescribed assumed north. To accomplish this, the observer sights on the orienting point with the correct azimuth setting. He then swings the instrument to the front, and is ready to observe and report. Auxiliary orientation points should be used and an aiming stake should be established not less than 100 yards from each observation post for night orientation. The orienting point may be any point of known direction from the observation post. The azimuth to the orienting point may be determined from the coordinates of these two points. The last station in a traverse to the observation post may be used. *Orientation must be checked repeatedly.*

a. Reciprocal orientation. When two or more observation posts are intervisible and one of them has been oriented properly, the others may be oriented reciprocally. (See fig. 109.)

b. Astronomic orientation. Orientation of instruments may be obtained or checked by an astronomic observation.

See paragraphs 57 and 58 for a discussion of procedure in obtaining an azimuth from sun or star observations. Orientation may be checked at any time by having all ob-

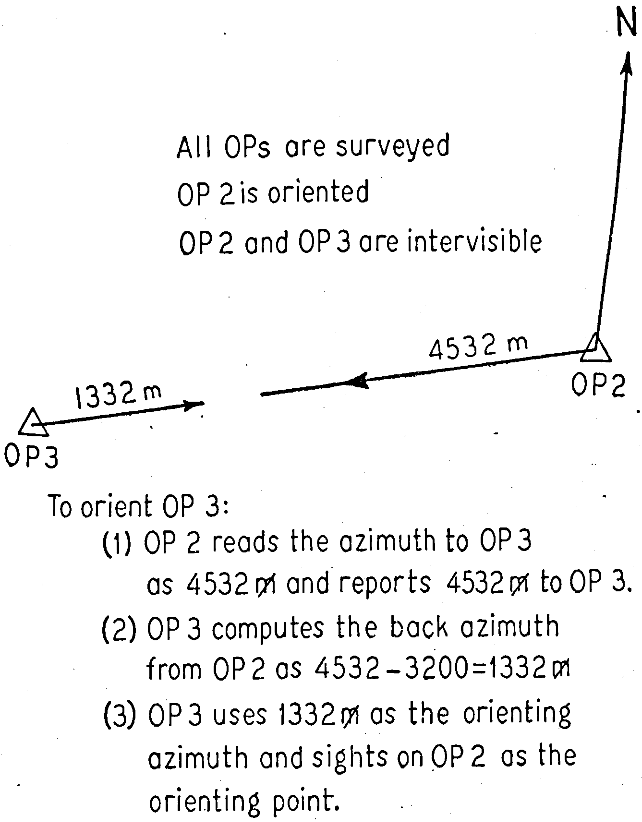


Figure 109. Reciprocal orientation.

servers sight simultaneously on the *same* astronomic body. If all instruments are oriented on a common direction they should all obtain the same reading to the astronomic body.

121. SURVEY METHODS. The survey of a flash observation post consists of two operations: determination of the coordinates and altitudes of the observation post; and determination of the orienting data for the observing instrument.

a. The observation posts should be located and altitudes determined by survey personnel using precise methods as described in chapter 4.

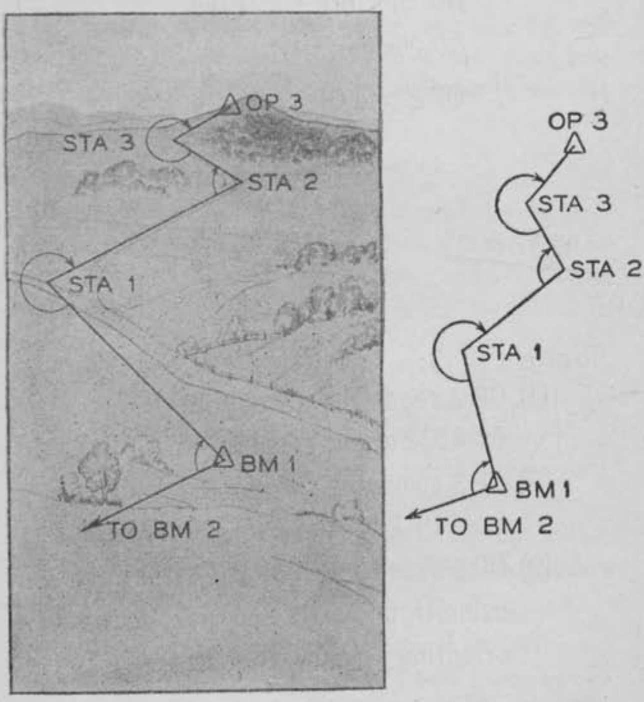


Figure 110. Location of an observation post by short traverse.

b. The coordinates of an observation post may be determined by a short traverse (fig. 110) without the use of

survey personnel if survey control is furnished to a point near the observation post. The observers traverse from the control point to the observation post using the observing instrument and a tape. This method is particularly valuable when—

(1) Survey personnel are unable to bring control to the exact position of the observation post because of security reasons.

(2) The exact location of the observation post has not been selected when the survey control is brought up to the general location of the observation post.

(3) The observation post has been moved a short distance after survey control has been established.

c. The coordinates of an observation post may be determined by resection without the use of survey personnel if sufficient points of known coordinates visible from the observation post exist in the area. Detailed procedure for performing a resection by the flash observing plotting personnel is discussed in paragraph 124.

122. PLOTTING. Rapid, accurate plotting for a deliberate flash ranging installation is best performed by means of a mechanical plotting board. (See fig. 111.) The flash plotting board is described in TM 9–2683. (See figs. 111 and 112.)

a. Numbering grids. The zero reading on the plotting board scale is north direction, in orienting the board for numbering grid lines. The grid lines must be so numbered as to include the area occupied by the observation posts and the target area, in their proper relation.

b. Plotting observation posts. The observation posts are plotted by coordinates on the plotting board, as carefully as possible, using a 2H or 3H pencil.

c. Orientation for observation posts. If the orienting point is a point in the target area, it may be plotted on the plotting board and the azimuth to it read from the plotting board and furnished to the observer. Orientation should be checked frequently to insure that the instrument has not been disturbed.

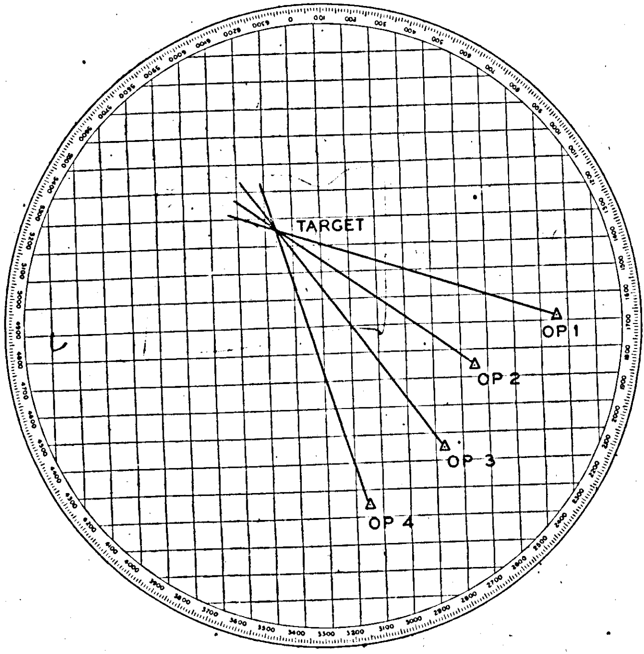


Figure 111. Flash ranging plotting board, M5, showing observation posts plotted for ranging northwesterly and rays drawn to a target.

d. Locations of points in target area. (1) As the azimuths from the observation posts are announced, they are set off on the azimuth scale and rays are drawn through the proper observation posts well into the target area. The intersection of these rays is the location of the target, the

coordinates of which are scaled from the plotting board.

(2) *Solution of the polygon of error.* The rays will

Figure 112. Flash plotting board, M5.

not always intersect at a point but frequently will form a polygon, called the polygon of error. (See fig. 55.) The

procedure for solving the polygon of error and for assessing an accuracy of plot is the same as described in paragraphs 83e and 93 for sound ranging plots.

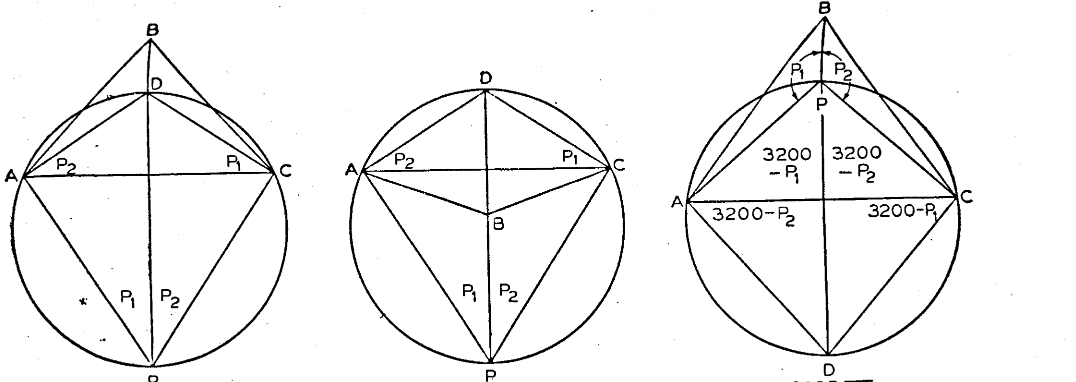
123. LOCATING OBSERVATION POSTS BY RESECTION. Resection methods may be employed to determine the location of an observation post without the use of survey personnel, if sufficient points of known coordinates visible from the observation post exist in the area.

a. Three-point resection (fig. 113). Three possible cases may arise in a three-point resection, depending upon the relative location of the three points of known coordinates to the location of the observation post to be located. Angles at the observation posts between the known points are read by the observers and reported to the plotting center where the position of the observation post is determined on the plotting board.

(1) *Procedure for cases I and II.* The observer at P reads angles P_1 and P_2. The azimuth from A to C is measured on the plotting board. The azimuth A to C minus P_2 is equal to the azimuth A to D. The azimuth from C to A (or 3,200 plus or minus the azimuth A to C) is measured on the plotting board. The azimuth C to A plus P_1 is equal to the azimuth C to D. The azimuth rays A to D and C to D are drawn on the board. The intersection of these rays fixes the point D.

Line BD extended is drawn on the plotting board and the azimuth from P to B (D to B) is measured.

The azimuth P to B minus P_1 is equal to the azimuth P to A. The azimuth rays P to A and P to C are drawn through A and C, respectively, on the plotting board. The intersection of these rays with the ray P to B fixes the



CASE I

CASE II

CASE III

CASE I & CASE II

Az A to C − P_2 = Az A to D
Az C to A + P_1 = Az C to D
Az P to B + P_2 = Az P to C
Az P to B − P_1 = Az P to A

CASE III

Az A to C + (3200 − P_2) = Az A to D
Az C to A − (3200 − P_1) = Az C to D
Az P to B − P_1 = Az P to A
Az P to B + P_2 = Az P to C

Points *A, B,* and *C* are three points of known coordinates. These points are plotted on the plotting board. Point *P* is the position of the observer and is to be located. In cases I and II, point *P* falls outside the triangle formed by the three known points. In case III, point *P* falls inside the triangle formed by the three known points.

Figure 113. Three-point resection.

point P unless the intersection results in a triangle. In this case, proceed by triangle of error method described below.

Note.—The point D is not a point on the ground. It is *only* a point on the circle that must be located to determine the azimuth P to B.

(2) *Procedure for case III.* The observer at P reads angles P_1 and P_2. The azimuth from A to C is measured on the plotting board. The azimuth A to C plus (3,200 minus P_2) is equal to the azimuth A to D. The azimuth from C to A (or 3,200 plus or minus the azimuth A to C) is measured on the plotting board. The azimuth C to A minus (3,200 minus P_1) is equal to the azimuth C to D. The azimuth rays A to D and C to D are drawn on the plotting board. The intersection of these rays fixes the point D.

Line BD extended is drawn on the plotting board and the azimuth from P to B (D to B) is measured.

The azimuth P to B minus P_1 is equal to the azimuth P to A. The azimuth P to B plus P_2 is equal to the azimuth P to C. The azimuth rays P to A and P to C are drawn through A to C, respectively, on the plotting board. The intersection of these rays with the ray P to B fixes the point P unless a triangle of error exists, in which case proceed by triangle of error method described below.

b. Triangle of error method. The position of an observation post may be located graphically by a three-point resection by the triangle of error method as follows: Assume an azimuth (as nearly correct as possible) from P to B. (See fig. 113.) Then the azimuth P to A = azimuth P to B minus P_1, and azimuth P to C = azimuth P to B plus P_2. Draw these azimuth rays through A, B, and C in the direction of point P. If the three rays do not intersect at one point, new azimuths must be assumed

for P to B, and the above procedure repeated until they do. For discussion of this method, see TM 5–235.

c. Two-point resection (fig. 114). Points A and B are two points of known coordinates. Points C and D are two points (observation posts) to be located. Points A and B are visible from both C and D.

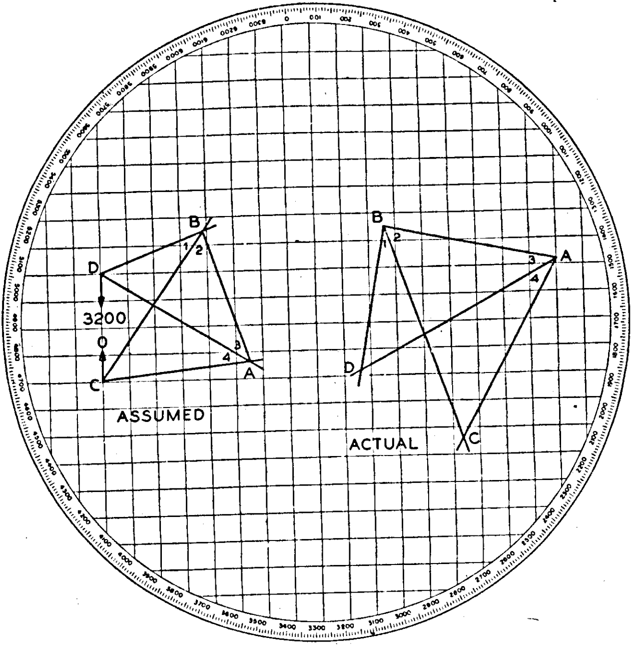


Figure 114. Two-point resection.

Observing instruments are set up at points C and D. The observer at C orients on D with 0 mils. The observer at D orients on C with 3,200 mils. With this orientation, both observers read angles to points A and B.

Assuming that C and D are oriented on zero azimuth (both zeroes on North), the angles read to A and B

become azimuths. Assume points *C* and *D* at any convenient location along a *Y* grid line (3,000 to 5,000 yards apart), and plot them on the plotting board. From *C*, draw azimuth rays to *A* and *B*. From *D*, draw azimuth rays to *A* and *B*. The intersection of the rays *C* to *B* and *D* to *B* determines the assumed location of point *B*. The intersection of the rays *D* to *A* and *C* to *A* determines the assumed location of point *A*.

Measure the assumed azimuths from *A* to *B* and *B* to *A* on the plotting board. Determine angle 1 as the difference between the azimuth *D* to *B* and *C* to *B*. Determine angle 2 as the difference between the azimuths *C* to *B* and *A* to *B*. Determine angle 3 as the difference between the azimuths *D* to *A* and *B* to *A*. Determine angle 4 as the difference between the azimuths *D* to *A* and *C* to *A*.

Plot the true positions of points *A* and *B* on the plotting board.

Measure the actual azimuths from *A* to *B* and *B* to *A* on the plotting board. Since the assumed figure and the actual figure are similar, all corresponding angles in the two figures are equal.

Determine the azimuth *B* to *C* by adding (subtracting) angle 2 to (from) the azimuth *B* to *A*. Determine the azimuth *A* to *C* by adding or subtracting (angles 3 + 4) to (from) the azimuth *A* to *B*. Draw azimuth rays *B* to *C* and *A* to *C* on plotting board. The intersection of these rays determines the actual location of point *C*.

Determine the azimuth *A* to *D* by adding or subtracting angle 3 to (from) the azimuth *A* to *B*. Determine the azimuth *B* to *D* by adding or subtracting (angles 1 + 2) to (from) the azimuth *B* to *A*. Draw azimuth rays *A* to *D* and *B* to *D* on plotting board. The intersection of these rays determines the actual location of point *D*.

d. Locating observation posts reciprocally (fig.

115.) OP 1 and *K* are plotted on the plotting board. OP 1 is located and oriented. The observer at OP 1 reads azimuth to OP 2. The observer at OP 2 sets this azimuth ±3,200 mils on his instrument and sights on OP 1 which orients OP 2.

OP 2 reads an azimuth to *K*.

Rays are now drawn on the board at the correct azimuth from OP 1 and *K* to OP 2, thus locating OP 2. (See fig. 115.)

Note.—It is desirable to have more than one known point in order to check on the location of OP 2.

124. OPERATING PROCEDURE. The observers, plotting team, and switchboard operator form a highly coordinated team; to function accurately and rapidly, a high degree of discipline must be maintained and a definite procedure of operation must be followed.

a. Organization. (1) *Observer team.* The observer team consists of a minimum of three men: observer, assistant observer, and recorder. Since observation posts must be manned continuously (24 hours a day) every man must be able to perform all duties required of the observer team, and additional men are necessary for an extended operation. Two men must be on duty at all times. The observer operates the instrument and reads the horizontal and vertical angles, and reports all information to the flash central. The assistant observer maintains a constant lookout in order to locate targets, collect combat intelligence, provide for local security, and keep all necessary records and sketches at the observation post.

(2) *Plotting team* (fig. 116). The plotting team consists of a minimum of three men: the armsetter, the draftsman, and the computer. These may be supplemented by a recorder, although the computer or the switchboard operator

may serve as recorder if reports are not arriving from the observers too rapidly.

(*a*) The armsetter sets and reads the mil scale of the plotting board.

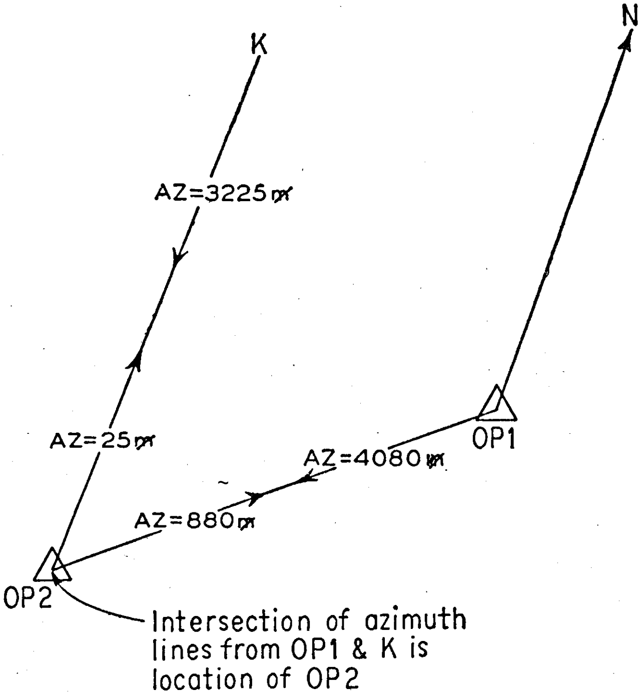


Figure 115. Location of observation posts reciprocally. OP 1 and OP 2 are intervisible, OP 1 is located and oriented. OP 2 is neither located nor oriented.

(*b*) The draftsman performs all drafting, reads coordinates and ranges, assesses accuracy of locations, and manipulates the plotting board.

(*c*) The computer determines altitude of targets and performs any other necessary computations.

Note.—Correction for curvature and refraction is applied for ranges over 5,000 yards. (See sec. IX, ch. 9.)

(*d*) The recorder maintains a record of the coordinates and altitude of each target plotted, accuracy of each plot, description of target, and time of location (FAS Form 6).

(3) *Switchboard operator.* The observers report all azimuths and sites to targets; announce accuracy of reading

Figure 116. Flash plotting team.

as Able, Baker, or Charlie, as described in paragraph 116c; execute all instructions to them by the switchboard operator; and maintain a record of their observations. *The switchboard operator is responsible for communication discipline and assists in observer control.* He records and announces to the plotting team the reports from the ob-

servers, and transmits to the observers data for orientation and approximate azimuths.

b. Plotting team procedure. (1) *Plotting azimuths.* The armsetter sets off on the scale of the plotting board the desired azimuth and reports "Set." The draftsman draws a ray through the proper observation post to the target area and reports "Line."

(2) *Reading azimuths from plotting board.* The draftsman rotates the board until the two points between which the azimuth is desired are properly aligned and commands "Read." The armsetter then clamps the board and reads aloud the scale setting.

(3) *Plotting targets.* When rays from at least three observation posts intersect, it may be safely assumed to be a target location. Reported azimuths from each observation post are plotted as in (1) above. The draftsman reads the coordinates of the target and assesses the accuracy of the plot, announcing to the recorder "Coordinates: 96.15–69.32, Accuracy 100 yards." He also reads and announces to the computer the range from the observation posts as: "Range from OP 2, 6175." The computer determines and announces the altitude of the target to the recorder as "Altitude, 517 yards." The recorder records and repeats back the coordinates, altitude, and nature of target, as he receives them.

c. Testing communication. Immediately upon completion of communication installations, the switchboard operator checks the switchboard circuits by the tests prescribed in TM 11–439, and the line circuits by ringing each observer in turn. If radio is being used as the means of communication, the test is essentially as given in the example below:

Switchboard operator calls: "OP 1."
Observer answers: "OP 1."
Switchboard operator: "Press your outpost key."

If there is no signal, the switchboard operator makes proper adjustments.

Switchboard operator: "Give me a ring."

The observer rings the switchboard.

Switchboard operator: "Roger."

This procedure is repeated, the switchboard operator calling each observation post in turn until all lines have been checked for outpost circuit, ringing circuit, and talking circuit.

d. Orienting observers. All circuits having been checked, the switchboard operator furnishes each observer orientation data, proceeding as follows:

Switchboard operator calls: "All OPs report when ready for orientation."

Each observer reports in turn.

Observers answer: "OP 1 ready."
"OP 2 ready . . . etc."

When all observers have reported:

Switchboard operator: "All OPs, orientation follows."

To each observer in turn:

Switchboard operator: "OP 1, orienting point, center of tower on little hill, azimuth 5103.2, Si plus 10."

Each observer repeats back data to switchboard operator:

Observer: "OP 1, orienting point, center of tower on little hill, 5103.2, Si plus 10."

When all observers have been oriented:

Switchboard operator: "All OPs, report when ready to observe."

Each observer replies in turn when ready to observe:

Observer: "OP 1, ready to observe."

When all observers have signified they are ready to observe, the switchboard operator announces to the plotting team:

"All observers are ready to observe."

e. Flash ranging location. (1) The instant a target is observed, the observers signal the switchboard.

Switchboard operator calls: "OP 1 (2), (3), (4), report."

Observer answers: "2561.2, Able, Si minus 5, enemy gun firing."

The switchboard operator records these data on the recording pad (FAS Form 3*b*, fig. 117) and repeats back the data to the observer loud enough for the armsetter of the plotting team to hear. Each observation post then reports in turn. The plotting team plots the target using the procedure outlined in b(3) above.

(2) If only one observer reports a target, the switchboard operator calls for an estimation of range from that observation post to the target.

Switchboard operator calls: "OP 1, report estimated range."

Observer answers: "4500."

The plotting team plots the approximate position of the target from these data and reads from the plotting board the approximate azimuth to the target for each of the other observation posts, announcing to the switchboard operator:

Draftsman: "OP 2, 1950."
"OP 3, 2150, etc."

The switchboard operator transmits these data to appropriate observers:

Switchboard operator: "OP 2, observe near 1950, enemy gun firing."

(3) If any two observers signal the switchboard simultaneously, they are probably observing the same flash. The switchboard operator calls for their reports; the plotting team plots the rays and determines approximate azimuths to the target for all other observers. The procedure is the same as outlined in (2) above.

(4) Standard forms for records are shown in chapter 9. Examples of the use of FAS Forms 3b and 6 are shown in figures 117 and 118.

FLASH-RANGING RECORD

File No.	Conc. No.	Date	Time Observed	Time Reported	Nature of Target	No. of Plots	Accuracy Yards	Caliber	Area Shelled
10	63	9-9-44	0922	0930	ENEMY GUN	3	50	88 m/	

Round No.	OP-1 Azimuth	OP-1 Site	OP-2 Azimuth	OP-2 Site	OP-3 Azimuth	OP-3 Site	OP-4 Azimuth	OP-4 Site	Coordinates X	Coordinates Y
Initial	6075.7	-07.4	6151.0	- 4.5	97.0	- 2.5	342.0	-5.0		
1	6093.4	-07.5	6155.0	- 5.0	100.5	- 3.0	342.5	-5.0	68 678	99 800
2	6078.8	-07.4	6153.0	- 5.0	97.3	- 2.5	342.0	-5.0	68 712	99 860
3	6088.9	-07.4	6156.5	- 5.0	98.0	- 2.5	342.0	-5.0	68 695	99 815
4										
5										
6										
7										
8										
9										
10										
Sum	18261.1	- 22.3	18464.5	-15.0	295.8	- 8.0	1026.5	-15.0	206 085	299 475
Mean	6087.0	- 07.4	6154.8	- 5.0	98.6	- 2.7	342.2	- 5.0	68 695	99 825
O-T Range	3368 yds.		3540 yds.		3450 yds.		3700 yds.			
Altitude of OP	1278 ft.		1259 ft.		1226 ft.		1257 ft.			
Target Alt. above OP ±	-75.		-53.		-28.		-55.			
Curv. and Refr. Corr. +	+ 2		+ 2		+ 2		+ 2		Sum Z	Mean Z
Z Coordinate	1205 ft.		1208 ft.		1200 ft.		1204 ft.		4817 ft.	1204.2 ft.

FAS Form No. 3b

F.A.S. Fort Sill, Okla., (6-12-44—40000)—29416 374 A

Figure 117. Sample record, FAS Form 3b.

Section IV. CONDUCT OF FIRE

125. GENERAL. a. Targets located by flash ranging normally are reported by coordinates. In the absence of a coordinate system common to both flash ranging and firing

RECORD OF SOUND- AND FLASH-RANGING LOCATIONS

Period Covered: Time 0001 ... Date 1 Jan. 1945 ... to Time 2400 ... Date 1 Jan. 1945 ... Sheet 1 of 3 Sheets

File No	Conc. No.	Source	Coordinates X	Coordinates Y	Coordinates Z	No. of Plots	Accuracy Yards	Nature of Target	Caliber	Area Shelled	Time Observed	Time Reported to Obsn. CP	Time Reported to Arty. CP	Mission Fired by	No. of Rounds	Effect
1	30	AS	96.340	972.460	1775	3	50	Enemy Btry.	170-mm	Unknown	1310	1315	1320	170th	72	Neutralized
2	37	BF	95.410	981.360	1455	4	30	Bn. C.P.	—	—	1315	1320	1325	172d	24	Destroyed
Number Consecutively	Assigned by FDC	F = Flash S = Sound A = Btry. "A" B = Btry. "B"		Z coordinate is in feet					Caliber of hostile artillery	Area shelled by hostile guns						

FAS Form No. 6 FAS, Fort Sill, Okla. (6-10-44—89000)—69418 371-37

Figure 118. Sample record, FAS Form 6.

units, sensings may be made in relation to a base point (check points or reference points). If conditions are favorable for a flash ranging adjustment "Will adjust" should follow the report of the target. The same general principles apply in the conduct of fire by flash ranging as by sound ranging.

b. When the battalion is operating under centralized control, reports of locations of targets are made to battalion operations section. Missions are evaluated and transmitted to corps artillery fire-direction center which assigns the mission to a firing unit, specifies the type of mission, the number of rounds to be fired, the channel of communication to be used, and designates a concentration number. Under decentralized control, targets are reported directly to the fire-direction center of the supported unit.

126. REGISTRATION. a. Observer procedure. The firing unit should furnish the coordinates and altitude of the registration point so that observers may be oriented to bring the first burst into their field of view. Time of flight and "On the way" should be announced by the firing unit to assist the observers in identifying the burst. (A code time of flight is used with radio communication.) As soon as the round appears in his field of view, the observer applies the reticle readings to the instrument scales to place the instrument cross hairs on the point of burst, and "clamps the instrument." The scale reading (clamping angles) are then reported to the flash plotting central. The instruments are not disturbed during the firing of the group of rounds for registration. Observers report reticle readings for each burst.

Example: Right (Left) 10, plus (minus) 5. The switchboard operator should check clamping angles at the completion of the registration. If these angles are not the same as

reported initially, the observations are unreliable and should be discarded. Particular care must be taken in reading the vertical angle. (See par. 146 for calibration of instruments.)

Note.—Reports from observers are given as follows:

(1) Observable rounds—*reticle readings* are reported, qualified as to accuracy as Able, Baker, or Charlie. (See par. 139.)

(2) Observable rounds outside of field of view—report *"Doubtful."*

(3) Nonobservable rounds—report *"Lost."*

The plotting central plots the initial round to make sure that all observers are observing the correct burst. Thereafter, all readings are evaluated by the plotting central and erratic readings are rejected. The plot for the registration is made by averaging the reliable readings for four to six rounds. Additional rounds may be requested if the desired results are not obtained because of erratic readings, lost rounds, or erratic dispersion of shell bursts.

b. Center of impact. The flash ranging unit may request one or more orienting rounds fired "At my command," in order to orient observers and assure positive identification of the initial rounds. Smoke shell may be specified to insure that the initial rounds are identified. It may specify the number of rounds (usually four to six) and the time interval between rounds to be fired in the group for registration, and signals "Fire" for the initial orienting rounds. "On the way" should be reported for each round. When the registration is completed, the coordinates and altitude of the center of impact are reported to the firing battalion.

c. High burst. High burst registration may be used when impact bursts (shell HE or smoke) would not be visible to observers. It differs from a center of impact registration in that air bursts are observed instead of ground bursts. Groups of rounds are fired as in b above, and the coordinates and altitude of the center of burst are reported.

127. ADJUSTMENTS. Adjustment is conducted by a single-piece firing two or more rounds with the best data available. The firing unit reports time of flight, azimuth of fire, and "On the way" for the initial adjusting round. The flash unit reports its sensings using forward observer methods. (See par. 129.) The adjustment is continued until the flash ranging unit estimates that the next shift will obtain effect on the target, at which time the next sensing will be followed by the command "Fire for effect." Adjustment by surveillance is continued during fire for effect.

128. TRANSFER OF FIRE. If surprise fire is desired and the target is located accurately, preliminary adjustment of fire on the target itself may be eliminated. It is the function of the firing battalion to determine whether prior registration is necessary and to choose the point for registration with the assistance of the flash ranging unit. The facilities of the flash ranging unit may be employed also to conduct bracket adjustments and precision adjustments for destruction.

129. EXAMPLE. An enemy battery has been located by Able Flash platoon and is reported to the battalion command post as follows:

"Flash Report, Coordinates 96.82–79.43, Altitude 315 yards, Enemy battery, 3 plots, Accuracy 50 yards, Time observed 0900, Will adjust."

Battalion evaluates this report and reports to corps artillery fire-direction center:

"Flash Report, Coordinates 96.82–79.43, Altitude 315 yards, Enemy battery located by Able Flash, Accuracy 50 yards, Time observed 0900, Will adjust."

Corps artillery fire-direction center directs the 170th Field Artillery Battalion to fire the mission and notifies the observation battalion accordingly. A concentration number

is assigned as well as the number of rounds to be fired and the channel of communication to be used. Direct communication is established between the flash ranging central and the fire-direction center of the firing unit.

The observation battalion notifies Able Flash to stand by to adjust the 170th Field Artillery Battalion.

FRC to FDC	FDC to FRC	Remarks
(1) Fire mission, Conc. No. 90, coordinates 96.82-79.43, altitude 315 yards, two rounds at my command. Report direction of fire and time of flight.	(2) Adjust battalion, Baker, direction of fire 160, time of flight 25 seconds. Battery is ready.	The flash plotting team plots the target and a line indicating the direction of fire through the target.
(3) Fire.	(4) On the way. (5) On the way.	Center of impact of adjusting rounds is plotted and the sensing is reported.
(6) 50 left, 10 below, 70 over, fire for effect when ready.	(7) Battalion firing for effect.	
(8) Deflection correct, 50 over, fire effective.		Fire for effect is corrected to place center of impact on target.

Note.—If common survey is not completed, the original location may be reported by forward observer sensing with respect to a base or check point. If time fire is used, additional adjusting rounds may be necessary to establish the proper height of burst over the registration point (auxiliary target). The procedure for a sound ranging adjustment is similar to a flash ranging adjustment except that sound ranging cannot furnish altitude or adjust high burst. (See sec. V, ch. 5.)

130. COMPARATIVE CALIBRATION OF FRIENDLY ARTILLERY. Comparative calibration is the comparison of

range quality of a given piece with those of another piece accepted as standard under the same firing conditions. The range of the standard piece being calibrated is determined by firing. The center of impact of a group of six rounds or more is used to calibrate each piece, for a given powder lot, projectile, and charge. The flash ranging unit performs the survey work necessary and observes the firing, reporting the coordinates and altitude of each round to the firing unit. The procedure is similar to a center of impact registration. See paragraph 126b and FM 6–40. The firing of all pieces should be completed in a short time to insure that all firing is conducted under the same weather conditions.

CHAPTER 7

RECONNAISSANCE, SELECTION, AND OCCUPATION OF POSITION

Section I. GENERAL

131. PURPOSE. The purpose of reconnaissance, selection, and occupation of position is to move a unit from a rendezvous or bivouac area, or from a march, into a position from which it can effectively accomplish its mission. A drill procedure for the reconnaissance and occupation of position is necessary in order to deploy the unit rapidly. It is neither possible nor desirable to lay down rigid rules for the composition of parties and the procedure to be adopted in every situation. Commanders are expected to make such modifications as the particular circumstance may require.

132. TASKS INVOLVED. Placing a battalion into position involves—

a. Reconnaissance for battery positions, flash and sound installations, command posts, routes into positions, wire routes, truck parks, and aid station.

b. Formulation of a plan for occupying the position selected.

c. Issuance of orders to carry out the plan.

d. Execution of the order, that is, the actual emplacement of the various elements of the battalion.

Section II. RECONNAISSANCE

133. GENERAL. As soon as the order for the employment of the battalion is received, a map and ground reconnaissance is made by the battalion commander and certain members of his staff. The battalion commander then issues his order to the battery commanders who, with their sound officers, flash officers, and communication officers, make a more detailed map and ground reconnaissance of positions for their installations. The position and type of sound base to be used, the location and type of flash installation, the wire routes, the locations of command posts, flash and sound ranging centrals, and the survey plan are determined from this reconnaissance. The considerations which determine the type of installation are fully discussed in chapters 2, 5, and 6.

134. PRINCIPLES. *The time allotted to reconnaissance generally is limited, and the procedure must be so organized that it can be accomplished as completely as possible in the time allotted.* Map reconnaissance can be made at any time but a ground reconnaissance is most effective during daylight hours. The size of the reconnaissance party usually is restricted to a minimum—*only essential vehicles and personnel.* The remainder of the unit remains in bivouac or rendezvous. Communication and survey personnel should be included in the reconnaissance echelon and the survey and communication operations should commence at once.

Section III. SELECTION OF POSITION

135. GENERAL. a. Position areas. For a full discussion of selection of positions, see chapters 2, 5, and 6. Figure 119 illustrates a typical layout of a battalion command post; figure 5 shows a typical layout of an observation battery in position.

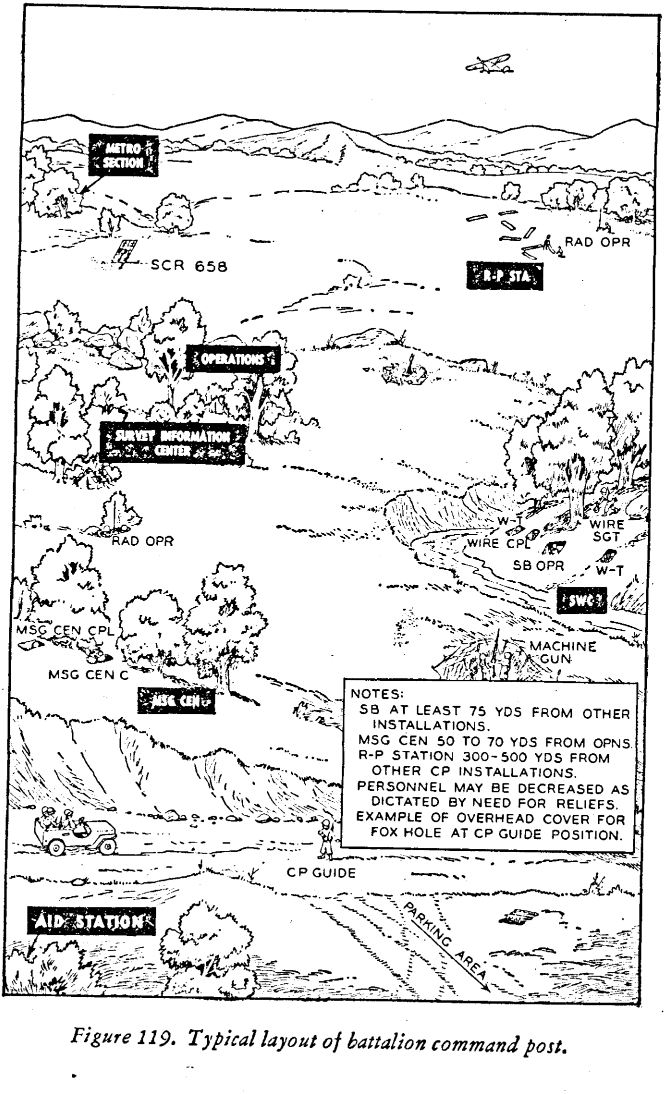


Figure 119. Typical layout of battalion command post.

b. Battalion command post. The locations of the observation battery positions generally determine the location of the battalion command post. Due consideration is given to local security, to ease of communication with the batteries and the supported artillery, and to the tactical situation. Ample and adequate area must be provided for headquarters and headquarters battery and for the operation of the metro section. In general, the battalion command post is in rear of and centrally located with respect to the two observation batteries.

136. SELECTION OF BATTERY POSITION. The battery command post is generally located in the center and to the rear of its sound and flash installations. The flash ranging central and sound ranging central are usually located to the rear of and in the center of their respective installations. Local security, the tactical situation, and communication considerations determine the positions to be occupied. The selection of sound and flash bases are discussed in chapters 5 and 6.

Section IV. OCCUPATION OF POSITION

137. GENERAL. After the reconnaissance and selection of position has been completed, survey and communication personnel usually are permitted to commence operations for the preparation of the new position. The remainder of the battalion will remain in bivouac or continue to operate in the old position until ordered to displace. The battalion normally displaces by battery. Installations are manned immediately and normal operations are commenced as soon as possible.

Section V. ORGANIZATION OF POSITION

138. LOCAL SECURITY. Without interfering with the operation of the unit, the position is organized for security.

Dispersal, camouflage, field fortification, establishment of machine guns, and posting of sentries are accomplished with the least possible delay by all personnel available. The organization of position begins when the position is selected, and continues throughout the occupation as opportunity permits.

139. INSTALLATIONS OF BATTALION COMMAND POST. The elements of a typical battalion command post

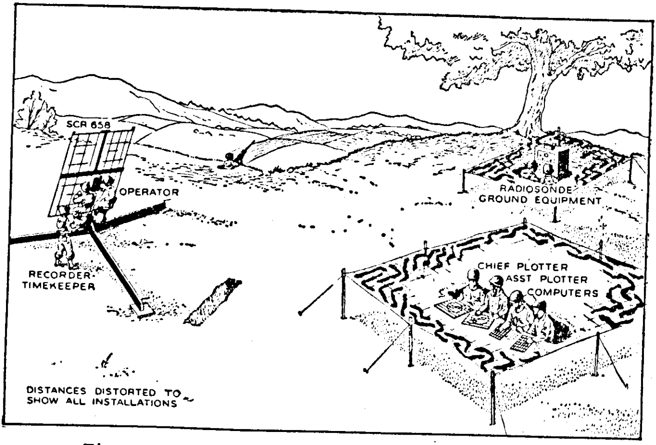


Figure 120. Organization of a typical metro section.

Note.—A command post tent, or other type of shelter, will normally be used to provide blackout protection and shelter in inclement weather.

are described in paragraph 33b. (See fig. 119.) In addition, the metro section normally will be located near the command post. (See fig. 120 for a typical metro installation.) The message center chief organizes the message center in the specified location. Agents and other messengers are stationed conveniently close and are controlled by the message center chief. A guide is posted near the entrance to the command post to indicate the location of in-

stallations to visitors, to control traffic, and to warn of presence of mines if necessary.

140. ORGANIZATION OF BATTERY POSITION AREA.

a. Battery command post. The battery command post is organized in the same manner as the battalion command post. Battery overhead is usually located near the battery command post.

b. Flash and sound ranging centrals. The flash and sound ranging centrals provide their own local security since these positions may be at some distance from the battery position area. The same general measures are taken, modified as necessary. (See figs. 121 and 122.)

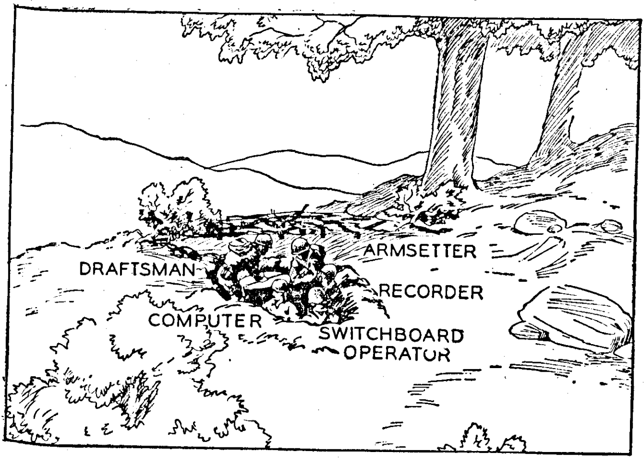


Figure 121. Organization of a typical, hastily dug-in, flash ranging central. Note: *A command post tent, or other type of shelter, will normally be used to provide blackout protection and shelter in inclement weather.*

c. Observation posts. Observation posts are dug in and protected by overhead cover and camouflage to the greatest extent possible in the time available. Typical observation posts, both hasty and prepared, are shown in figure

123. The assistant observer or the recorder acts as a sentry at each observation post. Defense measures consist *primarily* of passive measures of concealment, camouflage, and digging in. The observation post is of little or no value if

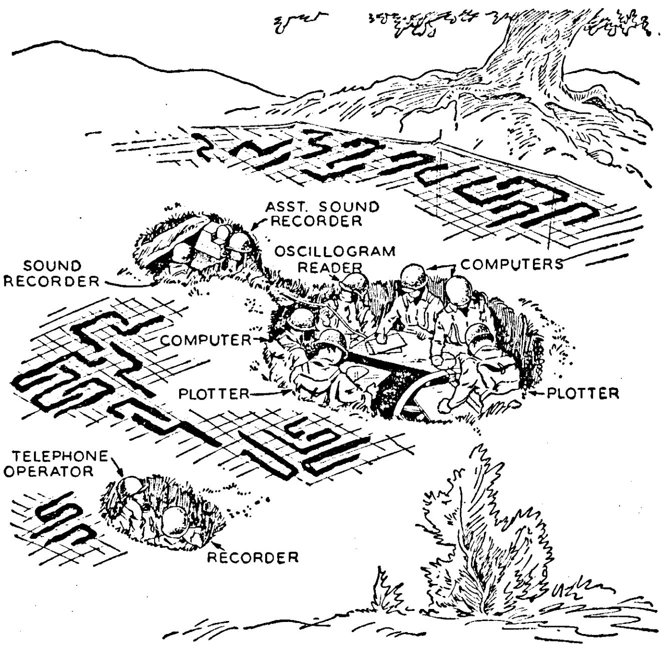


Figure 122. Organization of a typical, hastily dug-in sound ranging central. Note: *A command post tent, or other type of shelter, will normally be used to provide blackout protection and shelter in inclement weather.*

the enemy discovers it. Extreme care must be taken to keep it hidden. Only as a last resort will the personnel engage in active defense with small arms fire. Vehicles and radio are kept well away from the observation post, concealed, camouflaged, and defiladed.

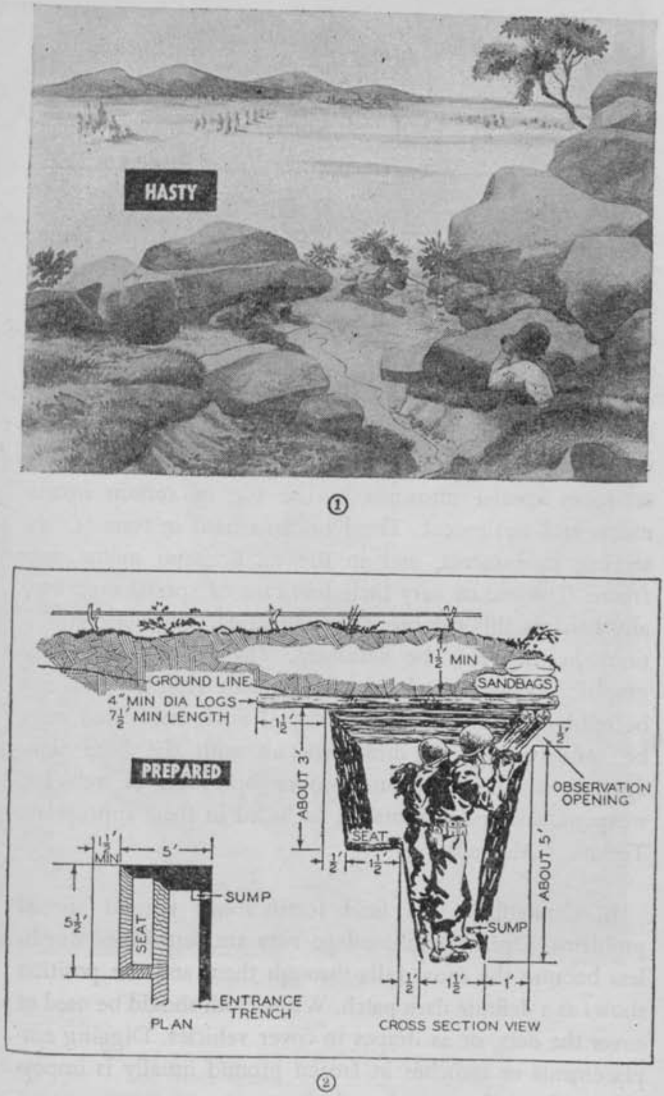


Figure 123. Organization of typical flash observation post.

CHAPTER 8

SPECIAL OPERATIONS

141. SNOW AND EXTREME COLD (see FM 70–15). **a.** The measures to overcome handicaps of snow and extreme cold are technical rather than tactical. Heavy snow greatly decreases mobility. It is sometimes necessary to replace trucks with track-laying vehicles. The use of trail-breaking vehicles to pack roads and trails in advance of wheeled or track-laying vehicles is recommended. Hand-drawn sleds or toboggans should be available. Extreme cold weather necessitates special measures in the use of certain instruments and equipment. The lubricants used in transits, observing instruments, and in the oscillograph motor may freeze. The use of very little lubricant of special type usually corrects this trouble, although under the worst conditions heating may be necessary. The activity of photographic developing solutions is seriously retarded and may be rendered entirely inactive. Metal equipment used must be insulated against direct contact with the bare skin. Special meaures to insure proper operation of vehicles, weapons, and instruments are included in their appropriate Technical Manuals.

b. Camouflage and field fortifications present special problems. Ordinary camouflage nets are sometimes worthless because the snow falls through them and the position shows as a definite dark patch. White cloth should be used to cover the nets, or as drapes to cover vehicles. Digging emplacements or trenches in frozen ground usually is impossible without the use of explosives.

Figure 124. Back pack.

Quantity	*Item*	*Weight (lb.)*
1	Sound ranging set GR–8–T2 plate supply and timer unit	37
1	Packboard	4¾
1	Blanket roll (approximately)	7
1	Musette bag (approximately)	5
	Total	53¾

Figure 125. Back pack.

Quantity	*Item*	*Weight (lb.)*
1	Reel RL 39 w/W130 wire.	13
2	Drum DR–8 w/W130 wire.	13
1	Packboard	4¾
1	Blanket roll (approximately)	7
1	Musette bag (approximately)	5
	Total	55¾

142. MOUNTAIN WARFARE. a. Mobility. The mobility of the observation battalion is limited in mountainous terrain. Motor travel usually is limited to roads, and speeds are considerably reduced. Frequently, equipment must be transported considerable distances by back pack or on pack animals, and installations made by man power or with the aid of pack animals. (See figs. 124 and 125.)

b. Observation. Observation posts should be echeloned in altitude, if possible, as well as in width and depth since observation is often obscured by sudden fog. Independent short bases may be the only type flash base that can be installed due to the difficulty of establishing survey and communication and of getting multiple observation posts that can observe in the same zone.

c. Employment. Operations are often decentralized to batteries. Oblique photos and overlapping pairs facilitate location of targets and vertical control. Generally, survey is accomplished by triangulation. Probable locations of targets are determined easily because the points that the enemy is compelled to pass and the areas in which he will form for attack may be determined usually by a study of the terrain.

d. Communication. Wire is hard to install and maintain. Radio reception is usually satisfactory but dead spaces should be expected due to the shadow effect of hill masses. These dead spaces may be overcome by making full use of the remote control unit or, in some cases, by the use of relay stations.

e. Reconnaissance and selection of position. *Extensive reconnaissance is necessary.* The selection of positions may be limited by inaccessibility and may be further limited by special requirements for flash and sound bases. Maps of

mountainous regions, if available, are seldom accurate. A correct appreciation of the terrain can be gained only by ground reconnaissance, supplemented by a study of air photographs or maps. The employment of local guides is often advantageous.

143. DESERT WARFARE (see FM 31–25). **a.** The observation battalion uses its normal installations in desert warfare. The lack of landmarks increases the difficulty of survey and target identification. Movement in desert country is largely dependent on some means of land navigation; careful adherence to a predetermined compass direction for a given distance is the most common method. Celestial navigation may sometimes be useful.

b. Ground observation frequently is limited by undulations of the terrain, shimmering atmosphere, dust, and sand storms. Portable observation towers may be very valuable where the terrain offers no natural vantage points. Sound ranging and flash ranging are employed to the maximum.

c. Natural concealment, except through defilade, is difficult. Protection against hostile shelling and air attack may be obtained by dispersion and field fortifications. Camouflage is used extensively. Security against hostile ground attack, especially armored attack, must be stressed.

144. JUNGLE WARFARE (see FM 72–20). **a. General.** The jungle does not change the principles of operation of the observation battalion but it does affect its application, chiefly by restricting observation, movement and supply.

b. Mobility. Motor movement in the jungle is retarded and slow, and is usually confined to roads and trails. Equipment will often have to be back packed, and sound and flash bases completely installed by hand, without the use of vehicles. Special equipment and packboards should

be provided. Organic means of transportation may be supplemented by boats and barges and by the use of sleds or carts drawn by animals or man power, tractors and amphibious vehicles. (See figs. 124 and 125.)

c. Observation. Flash observation in the jungle is extremely limited. Personnel must be trained to exploit available commanding ground. Careful scrutiny and the ability to identify all types of enemy installations, weapons, and transport are very important. Observation is usually difficult because of very large trees with dense interlacing foliage; the undergrowth is massive. If every man carries a machete or bush knife, a limited field of view can often be cut from the undergrowth. Observation posts should always have overhead cover because overhanging foliage often causes tree bursts. Personal reconnaissance is a prime necessity in choosing the location of observation posts or other installations. Always notify all adjacent troops before climbing trees to gain observation. Security for the observer is important because enemy patrols may infiltrate into the position. Observers may accompany reconnaissance patrols in order to locate targets. Infantry patrol leaders often return by way of artillery observation posts to point out targets they have located. Sound ranging is often the only observation possible. Observation from boats off shore may be feasible in coastal regions. Climate, weather, insects, and animals also present problems to the observer.

d. Conduct of fire. (1) Registration and adjustment usually will be conducted by sound ranging. Difficulties in survey in jungle terrain may make deliberate occupation of position extremely slow, especially in the initial phases of the operation. In many cases, irregular bases, located by shooting in or by inspection of air photos, will be used. Relative sound ranging locations and *sound-on-sound* adjustments will play major roles. Where laying of wire is

difficult, initial use of radio for sound data transmission may speed up early operation.

(2) Flash ranging high burst registration and adjustment may be used advantageously. As a rule, ground bursts will be obscured by jungle growth and trees.

e. Communication. (1) Wire is the principal means of ground communication. The supply of wire and the means of laying it are usually limited; much wire has to be laid by hand. Initially, existing trails may have to be used for line routes but later circuits should be rerouted through the jungle or buried along the original route. Wire parties may require protection by accompanying patrols.

(2) The range of radio is greatly reduced. Waterproofing and fungiproofing equipment are critically important in humid areas and during rainy seasons. Dismounted messengers are used extensively. Oral messages are preferable because the danger of written matter falling into enemy hands is relatively great.

f. Positions. Good positions are usually few in number and are limited to locations near existing roads or trails. In many cases it will be necessary to clear a position, and construct a road prior to occupation.

g. Survey. Reliable maps may not be available. Aerial photographs are valuable but important terrain features are often obscured by dense vegetation. Survey is of particular importance because of the reliance placed on unobserved fires. It is slow because of the amount of brush cutting necessary. Usually, the target area must be tied to the position area by firing.

h. Local security. Camouflage and concealment are relatively easy. Overhead cover for personnel is necessary because bombs and other projectiles are likely to burst in the treetops. Ground attack by infiltration is always a

threat; each battery and similar installation must establish a strong perimeter defense.

145. LANDING OPERATIONS. The observation battalion is seldom in the assault waves of an amphibious operation; however, its forward echelons, battery and battalion, must be landed as early as possible in the operation. Preparation for landing operations is extremely important. Prior knowledge of terrain from intensive map study and knowledge of enemy dispositions are essential. Information on the progress and whereabouts of our own troops is also of extreme importance. Special precautions must be taken to waterproof vehicles and to protect equipment (weapons, communication equipment, flash ranging and sound ranging equipment, etc.) from exposure (immersion, spray, or dampness) to salt water. All equipment must be carefully cleaned immediately after exposure. In loading, precautions must be taken to facilitate entry into action; equipment needed first should be readily available. Reconnaissance parties should be first ashore to reconnoiter routes and select positions for installations. Survey personnel and equipment must also be landed early. To facilitate survey, existing maps should be studied thoroughly so that prominent terrain features can be identified for orientation and for use in installations as soon as the units are landed. A minimum of 3 days rations should be provided the landing parties.

CHAPTER 9

REFERENCE DATA

Section I. ADJUSTMENTS AND CALIBRATION OF INSTRUMENTS

146. ADJUSTMENT AND CALIBRATION OF INSTRUMENTS. a. General. Azimuths and angles of site must be taken accurately in order that locations or adjustments should be of value. It is necessary that instruments should be in adjustment or that the error of the instrument should be known and a correction applied. The adjustment of transits or observing instruments may be made or the error determined by methods described in TM 5–235. An instrument can be checked by comparison with other instruments, by multiple measurement of the same angle, or by closing the horizon, as discussed in chapter 4.

b. Angle of site adjustment. The angle of site adjustment must be made frequently, as transportation across country makes it difficult to keep instruments in adjustment. The adjustment can be made by the "peg" method described in TM 5–235. A quick method of checking the angle of site error in an instrument is by calibration as follows:

Two instruments, A and B, are set up approximately at the same height, facing each other with their objective lenses about 2 feet apart, and adjusted so that the cross hairs of each instrument can be seen in the other. The bubbles are carefully leveled and a reading is taken by each instrument to the horizontal cross hair of the other. If the two instruments are in perfect adjustment, the read-

ings will be the same. If the readings are different, their algebraic sum is the algebraic sum of the errors in the two instruments. Both instruments are then laid on the same distant object and the angle of site to this distant object is read on each instrument. The difference between these two readings is the algebraic difference of the errors of the two instruments. Having found the algebraic sum and the algebraic difference of the two errors, these errors may be determined by solution of a pair of algebraic equations, as illustrated in the example below:

Let a be the error in instrument A, and b the error in instrument B. When reading on the horizontal cross hair of the other, instrument A read -6 mils, and instrument B read 0 mils. Then:

$$a + b = -6 \text{ mils} \qquad (1)$$

When reading to the distant object, A read 45 mils and B read 43 mils. Then:

$$a - b = +2 \text{ mils} \qquad (2)$$

Adding equations (1) and (2):

$$2a = -4$$
$$a = -2 \text{ mils}$$

Substitution of this value of a in either (1) or (2) gives:

$$b = -4 \text{ mils}$$

This means that the vertical angle scale of instrument A reads 2 mils too low. The correction to be applied to any angle of site measured by this instrument is therefore $+2$ mils. Similarly, the correction for instrument B is $+4$ mils.

The error found for each instrument and the instrument number should be reported to the plotting central. Care must be taken to avoid confusing the instrument error with the correction: in the example instrument A has an *error* of -2 mils, so the *correction* is $+2$ mils.

Before departing for the observation post, each observer will, if time permits, ascertain his instrument error by the method described above. If possible, instrument adjustment will be performed independently by each observer, and results compared.

Section II. IMPROVISED SOUND RANGING PLOTTING BOARD

147. MOUNTING DRAWING PAPER ON PLOTTING BOARD. The drawing board on which paper is to be mounted should be ¾-inch hardwood, reinforced by strips on the back to prevent warping, or ¾-inch plywood. Any varnish or shellac is removed from the top surface, the edges, and from a 3-inch margin all the way around the back surface of the board; and these surfaces are smoothed with a fine grade of sandpaper. A good grade of fine-grained surface drawing paper (medium thickness) is cut to a size 6 inches larger in length and width than the board. The paper is saturated with water and allowed to stand about 5 minutes; the surplus water is then wiped off. The prepared surface of the board is dampened, and covered with a thin coat of good glue. The wet paper is placed on and stretched over the board, and the edges turned over, saw-toothed, and glued to the edges and back of the board. Thus the drawing paper is glued to the board at every point. The board is then weighted down to hold the paper in position until dry (about 48 hours).

148. LAYING OFF TIME SCALES FOR SOUND PLOTTING. A convenient way to lay off time scales for sound plotting is by the tangent method. Tables for this purpose are included in this chapter. (See sec. XIII.) Similar tables may be made up for other lengths of sub-bases by determining from trigonometric tables the tangents of the angles θ whose sines are equal to t/s for various values of t.

To lay off a time scale for a sub-base M_1M_2 (fig. 126), the perpendicular bisector CO of the sub-base is drawn. An arc, along which the time scale graduations are to be drawn, is constructed at a convenient place. This arc is not necessarily concentric about C. At D, a convenient distance from C (for example, 10,000 yards at the scale of

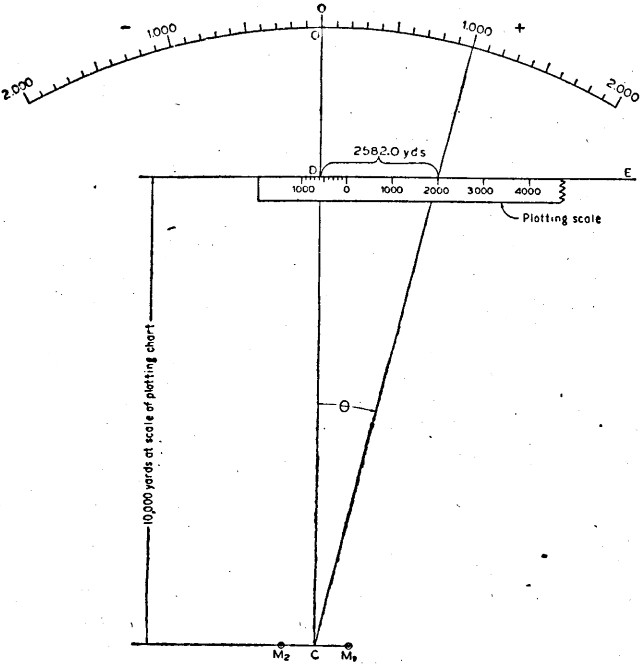


Figure 126. Laying off time scales.

the plot), a line DE is drawn perpendicular to CO. To lay off the graduation for a time interval t, the corresponding tangent is found from the proper table. This tangent is multiplied by the distance CD (10,000 yards) and the resulting distance is scaled off from D along the line DE. Points are located to the right for positive values of t, and

to the left for negative values of t. A straightedge is laid from C to each point so located on DE, and the line extended to locate a corresponding point on the arc. Referring to figure 126, the sub-base s is 4 sound seconds. Assuming a time interval t of 1 second, tan θ, from the table in paragraph 173 is 0.25820. If CD is 10,000 yards, the point for $t = +1$ is laid off $0.25820 \times 10{,}000 = 2582.0$ yards at the scale of the plot, along DE to the right of D. This point, projected in line with C to the arc, locates the graduation for $t = +1$ second. Graduations for other values of t are located in a similar manner, by laying off distances corresponding to positive time intervals to the right of D, and for negative time intervals to the left of D. After completing graduations corresponding to the time intervals listed in the tables, the scales are further subdivided by interpolation, usually to one-hundredth-second intervals.

Section III. ABBREVIATIONS

149. GENERAL. The following special abbreviations are used in this manual:

α	—bearing angle
β	—offset angle between successive sub-bases (regular curved base)
C	—midpoint of a sub-base
CP	—command post
D and R	—direct and reversed (readings of a transit
FDC	—fire-direction center
FRC	—flash ranging central
L	—long chord of a regular curved base
M (M_1, M_2, etc.)	—microphone
OP	—observation post, outpost
r	—radius of circle through midpoints of sub-bases (regular curved base)

R — radius of circle through microphones (regular curved base)
s — length of sub-base in sound seconds
Si — angle of site
SIC — survey information center
SRC — sound ranging central
SWC — switching central
T (T_1, T_2, etc.) — time of travel of sound from source to microphone
t (t_1, t_2, etc.) — time interval between arrival times at adjacent microphones
θ — angle between reference line of sub-base and asymptote
V — velocity of sound under standard conditions
V_x — velocity of sound at temperature X
W — wind velocity
ω — angle between sound path and wind direction
ϕ — angle between sub-base and wind direction

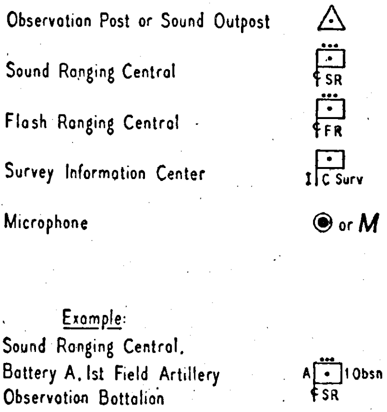


Figure 127. Symbols.

Section IV. SYMBOLS

150. GENERAL. For special symbols used in this manual, see figure 127.

Section V. USEFUL TRIGONOMETRIC FORMULAE

151. RIGHT TRIANGLE. In the right triangle *ABC* (fig. 128):

$$c^2=a^2+b^2$$

$$\text{sine (sin) } A=\frac{a}{c}=\cos B$$

$$\text{cosine (cos) } A=\frac{b}{c}=\sin B$$

$$\text{tangent (tan) } A=\frac{a}{b}=\cot B$$

$$\text{cotangent (cot) } A=\frac{b}{a}=\tan B$$

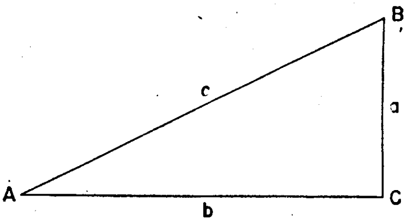


Figure 128. Right triangle.

152. OBLIQUE TRIANGLE. In the oblique triangle *ABC* (fig. 129):

$$\frac{a}{\sin A}=\frac{b}{\sin B}=\frac{c}{\sin B} \qquad \text{(law of sines)}$$

$$c^2=a^2+b^2-2ab\cos C \qquad \text{(law of cosines)}$$

$$\frac{a-b}{a+b}=\frac{\tan \frac{1}{2}(A-B)}{\tan \frac{1}{2}(A+B)} \qquad \text{(law of tangents)}$$

$$\tan A=\frac{a \sin C}{b-(a\cos C)}$$

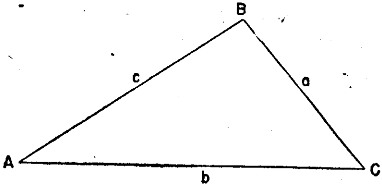


Figure 129. Oblique triangle.

153. ASTRONOMIC TRIANGLE. In the astronomic triangle PZS (fig. 18):

$$\tan \tfrac{1}{2} A = \sqrt{\frac{\sin (s-h) \sin (s-\phi)}{\cos s \cos (s-p)}} \quad \text{(altitude methods)}$$

$$\tan A = \frac{\sin t}{\cos \phi \tan s - \sin \phi \cos t} \quad \text{(hour angle method)}$$

where O = position of observer
P = north celestial pole
Z = zenith
S = position of celestial body
A = azimuth to celestial body (east or west of true north)
ϕ = latitude of place of observation
h = altitude JS of celestial body
δ = declination MS of celestial body
p = polar distance $PS = 90° - \delta$
$s = \tfrac{1}{2}(\phi + h + p)$
t = hour angle of celestial body.

154. FUNCTIONS OF ANGLES. Functions of angles in any quadrant in terms of angles in the first quadrant:

	$-\alpha$	$90° \pm \alpha$	$180° \pm \alpha$	$270° \pm \alpha$
sin	$-\sin \alpha$	$+\cos \alpha$	$\mp \sin \alpha$	$-\cos \alpha$
cos	$+\cos \alpha$	$\mp \sin \alpha$	$-\cos \alpha$	$\pm \sin \alpha$
tan	$-\tan \alpha$	$\mp \cot \alpha$	$\pm \tan \alpha$	$\mp \cot \alpha$
cot	$-\cot \alpha$	$\mp \tan \alpha$	$\pm \cot \alpha$	$\mp \tan \alpha$

Section VI. EXAMPLES OF COMPUTING FORMS

155. COMPUTING FORMS. See figures 130 to 142, inclusive.

AZIMUTH AND DISTANCE FROM COORDINATES

Stations	X	Y
From	(–)	(–) ....
To	(+)	(+) ....
	ΔX	ΔY ....

Log ΔX ....

—Log ΔY ....

$\text{Tan } \alpha = \dfrac{\Delta X}{\Delta Y}$ $\qquad D = \dfrac{\Delta X}{\text{Sin } \alpha} = \dfrac{\Delta Y}{\text{Cos } \alpha}$

Log Tan α .... $\qquad \alpha$ ....

....

Log ΔX* .... $\qquad$ Azimuth ....

—Log Sin α* ....

Log D .... $\qquad$ D .... yards

SKETCH

0°

X– Y+ | X+ Y+

270° | 90°

X– Y– | X+ Y–

180°

Stations	X	Y
From	(–)	(–) ....
To	(+)	(+) ....
	ΔX	ΔY ....

Log ΔX ....

—Log ΔY ....

$\text{Tan } \alpha = \dfrac{\Delta X}{\Delta Y}$ $\qquad D = \dfrac{\Delta X}{\text{Sin } \alpha} = \dfrac{\Delta Y}{\text{Cos } \alpha}$

Log Tan α .... $\qquad \alpha$ ....

....

Log ΔX* .... $\qquad$ Azimuth ....

—Log Sin α* ....

Log D .... $\qquad$ D .... yards

SKETCH

0°

X– Y+ | X+ Y+

270° | 90°

X– Y– | X+ Y–

180°

*Note: If ΔX is less than $\frac{1}{2}\Delta Y$, enter Log ΔY instead of Log ΔX and Log Cos α instead of Log Sin α in these spaces.

FAS Form No. 1 $\qquad$ FAS, Fort Sill, Okla., (10-3-44—20,000)—30159 363-364 A

Figure 130. FAS Form 1.

COORDINATES FROM AZIMUTH AND DISTANCE

Traverse from ______ to ______ Sheet ______ of ______ Sheets

Station	Azimuth	°	′	″	Direction to Next Station	Distance to Next Station	Logarithms		Coordinates and X and Y Differences	
Sta. BM 2	Az. to Next Sta.									
	±	180	00	00			Note: To find ΔX and ΔY in meters, use log of distance in feet, and add 9.484 0158.			
Sta. BM 1	Az. to Last Sta.	328	06	24	X− Y+ / Y / X+ Y+				X 462 445 50	Y 726 048 70
	Angle Turned	103	20	56		3) 315630 ft.				+ Scale Error 335 x 2.98 = +0.99
	Sum	431	27	20	X− Y− / X+ Y−	D = 1052.10 yd.	D 3 0220570	D 3 0220570		
	−	(360	00	00)			Sin α 9 9768437	Cos α 9 5024820		
	Az. to Next Sta.	71	27	20	α = 71° 27′ 20″		ΔX 2 9989007	ΔY 2 5245390	ΔX + 997 47	ΔY + 334 61
	±	180	00	00						
Sta. NO. 1	Az. to Last Sta.				X− Y+ / Y / X+ Y+				X 463 442 97	Y 726 384 30
	Angle Turned					3) ...... ft.				
	Sum				X− Y− / X+ Y−	D = ... yd.	D	D		
	−	(360	00	00)			Sin α	Cos α		
	Az. to Next Sta.				α = ° ′ ″		ΔX	ΔY	ΔX	ΔY ......
	±	180	00	00						
Sta.	Az. to Last Sta.				X− Y+ / Y / X+ Y+				X	Y ......
	Angle Turned					3) ...... ft.				
	Sum				X− Y− / X+ Y−	D = ... yd.	D	D		
	−	(360	00	00)			Sin α	Cos α		
	Az. to Next Sta.				α = ° ′ ″		ΔX	ΔY	ΔX	ΔY ......
	±	180	00	00						
Sta.	Az. to Last Sta.				X− Y+ / Y / X+ Y+				X	Y ......
	Angle Turned					3) ...... ft.				
	Sum				X− Y− / X+ Y−	D = ... yd.	D	D		
	−	(360	00	00)			Sin α	Cos α		
	Az. to Next Sta.				α = ° ′ ″		ΔX	ΔY	ΔX	ΔY ......
Sta.	Computer				Checker		Date		X	Y ......

FAS, Form No. 2 FAS, Fort Sill, Okla. (8-19-44—350,000)—29436 577-879-A

Figure 131. FAS Form 2.

Orienting Data For Flash-Ranging Observation Posts

Date__________ Time__________ Position__________

OP No.	Coordinates of Observation Posts			Orienting Point		
	X	Y	Z	Description	Azimuth	Site
1						
2						
3						
4						

Orienting Data For Flash-Ranging Observation Posts

Date__________ Time__________ Position__________

OP No.	Coordinates of Observation Posts			Orienting Point		
	X	Y	Z	Description	Azimuth	Site
1						
2						
3						
4						

Orienting Data For Flash-Ranging Observation Posts

Date__________ Time__________ Position__________

OP No.	Coordinates of Observation Posts			Orienting Point		
	X	Y	Z	Description	Azimuth	Site
1						
2						
3						
4						

FAS Form No. 3a

FAS, Fort Sill, Okla., (10-3-44—3,000)—30181 862-A

Figure 132. FAS Form 3a.

FLASH-RANGING RECORD

File No.	Conc. No.	Date	Time		Nature of Target	No. of Plots	Accuracy Yards	Caliber	Area Shelled
			Observed	Reported					

Round No.	OP-1		OP-2		OP-3		OP-4		Coordinates	
	Azimuth	Site	Azimuth	Site	Azimuth	Site	Azimuth	Site	X	Y
Initial										
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
Sum										
Mean										
O-T Range										
Altitude of OP										
Target Alt. above OP ±										
Curv. and Refr. Corr. +									Sum Z	Mean Z
Z Coordinate										

FAS Form No. 3b

FAS, Fort Sill, Okla. (10-10-44—2,800)—30142 376-A

Figure 133. FAS Form 3b.

SHORT-BASE FLASH-RANGING RECORD

File No.	Conc. No.	Date	Time		Nature of Target	No. of Plots	Accuracy Yards	Caliber	Area Shelled
			Observed	Reported					

Angle	Mils	Range	Site		Coordinates	
			L OP	R OP	X	Y
L	+					
−R	−					
t						
L	+					
−R	−					
t						
L	+					
−R	−					
t						
L	+					
−R	−					
t						
L	+					
−R	−					
t						
L	+					
−R	−					
t						
L	+					
−R	−					
t						
L	+					
−R	−					
t						
L	+					
−R	−					
t						
		Sum				
		Mean				
		O-T Range Altitude of OP Target Altitude above OP ±				
		Curvature and Refraction Correction	+	+	Sum Z	Mean Z
		Z Coordinate of Target				

FAS Form No. 3c

FAS, Fort Sill, Okla., (10-2-44—10,0(0)—30163 370-371-A

Figure 134. FAS Form 3c.

SOUND PLOTTING RECORD

Base: Location.................. Type.................. Azimuth.............. Date..............

Oscillogram No.............. Time.............. Temperature..............°F Wind: Direction..............mils Speed..............mph

Time Readings

Results to (−)					
1	2	3	4	5	6
Results to (+)					

	1		2		3		4		5	
	+	−	+	−	+	−	+	−	+	−
Time Interval										
Curvature Correction										
Temperature Corr.										
Wind Correction										
Sub-Totals										
Subtract										
Corrected Time Interval										
Approximate Range										

Coordinates: X.............. Y.............. Accuracy..............yards Caliber.............. File No..............

Area Shelled.............. No. of Pieces.............. Time Reported.............. Conc. No..............

FAS Form No. 4 FAS Fort Sill, Okla., (10-4-44—6,000)—30164 567-368-A

Figure 135. FAS Form 4.

SURVEY LOCATIONS

Date..........................

Sheet No..............

Station		Azimuth and Distance to Other Stations			Description of Station Listed in First Column	
Name	Coordinates	Sta. Name	Azimuth	Distance, Yds	General Location	Location and Description
	X					
	Y					
	Z					
	X					
	Y					
	Z					
	X					
	Y					
	Z					
	X					
	Y					
	Z					
	X					
	Y					
	Z					
	X					
	Y					
	Z					

FAS Form No. 5

FAS, Fort Sill, Okla., (6-19-44—24000)—29422

Figure 136. FAS Form 5.

RECORD OF SOUND- AND FLASH-RANGING LOCATIONS

Period Covered: Time.................. Date.. to Time.................. Date.. Sheet............ of ....Sheets

File No.	Conc. No.	Source	Coordinates			No. of Plots	Accuracy Yards	Nature of Target	Caliber	Area Shelled	Time Observed	Time Reported to		Mission Fired by	No. of Rounds	Effect
			X	Y	Z							Obsn. CP	Arty. CP			

FAS Form No 6

FAS, Fort Sill, Okla., (8-10-44—80000)—89418 871-875-A

Figure 137. FAS Form 6.

WEATHER DATA FOR SOUND RANGING

Location .... (of Weather Station) Date .... No. ....

Dry Bulb Temperature .... F.

Wet Bulb Temperature* .... F.

Virtual Temperature* .... F.

*Not required when dry bulb temperature is less than 60F.

Minutes	Elevation Angle, Degrees	Azimuth Angle, Degrees	Horizontal Distance, Yards	Wind Direction, Mils	Wind Speed, mph
½ (Surface)			——		
1					
2					
3					
4					

Wind Structure	Weighting Factors (Check and use one column) Normal	(2)	(3)	(4)	Weighted Wind Direction	Weighted Wind Speed
Second Minute Wind Speed is:	1 to 2 Times First Minute Wind Speed	Over 2 Times First Minute Wind Speed	Less than 1st Min. and within 2 mph of Surface Wind	Less than 1st Min. and not within 2 mph of Surf. Wind		
Surface	0.2	0.4	0	0		
1st Min.	0.5	0	1.0	0		
2d Min.	0.15	0.3	0	1.0		
3d Min.	0.075	0.15	0	0		
4th Min.	0.075	0.15	0	0		
				Total		

DATA REPORTED TO SOUND-RANGING SECTIONS

Effective Temperature .... F. Wind Direction .... mils. Speed .... mph Time .... (of last reading on balloon)

Transmitted to .... by .... (Msgr, Tp, etc.) Time .... Message Delivered to .... (Rank, Name)

Transmitted to .... by .... (Msgr, Tp, etc.) Time .... Message Delivered to .... (Rank, Name)

Observer .... Reader .... Plotter ....

FAS Form No. 7

FAS, Fort Sill Okla., (10-4-44—6,000)—30197 361-A

Figure 138. FAS Form 7.

COMPUTATION OF TRIANGLES

Triangle ______ SKETCH*

Stations		Observed Angles °	'	"	Adjusted Angles °	'	"
______	(A)*						
______	(B)*						
______	(C)*						

Log BC ______
Colog Sin A ______
Log Sin B ______
Sum — Log AC ______
Stations: A ______ C ______

Log BC ______
Colog Sin A ______
Log Sin C ______
Sum — Log AB ______
Stations: A ______ B ______

Triangle ______ SKETCH*

Stations		Observed Angles °	'	"	Adjusted Angles °	'	"
______	(A)*						
______	(B)*						
______	(C)*						

Log BC ______
Colog Sin A ______
Log Sin B ______
Sum — Log AC ______
Stations: A ______ C ______

Log BC ______
Colog Sin A ______
Log Sin C ______
Sum — Log AB ______
Stations: A ______ B ______

Triangle ______ SKETCH*

Stations		Observed Angles °	'	"	Adjusted Angles °	'	"
______	(A)*						
______	(B)*						
______	(C)*						

Log BC ______
Colog Sin A ______
Log Sin B ______
Sum — Log AC ______
Stations: A ______ C ______

Log BC ______
Colog Sin A ______
Log Sin C ______
Sum — Log AB ______
Stations: A ______ B ______

Triangle ______ SKETCH*

Stations		Observed Angles °	'	"	Adjusted Angles °	'	"
______	(A)*						
______	(B)*						
______	(C)*						

Log BC ______
Colog Sin A ______
Log Sin B ______
Sum — Log AC ______
Stations: A ______ C ______

Log BC ______
Colog Sin A ______
Log Sin C ______
Sum — Log AB ______
Stations: A ______ B ______

*Note: In each triangle, make BC the side of known length.

Computed by ______ Date of Computation ______

FAS Form No. 8

FAS, Fort Sill, Okla., (10-2-44—11,800)—[illegible]

Figure 139. FAS Form 8.

LEVELING WITH ALTIMETERS — FIELD OBSERVATIONS AND COMPUTATIONS

Instrument No.________ Weather________________ Observer________________ Recorder________________ Date________

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Field Station Data														
Station	Time	Altimeter Reading	Temp.	Mean Temp.	Index Diff. ±	Field Alt. Indexed (3+6)	Base Sta. Altimeter Reading	Indicated Diff. (7−8)±	Temp. Corr. ±	Diff. Corrected (9+10)±	Unadj. Altitude	Clos. Adj. ±	Adjusted Altitude	Known Altitude

Computed by ________________ Checked by ________________ Date ________

FAS Form No. 9

FAS, Fort Sill, Okla., (10-9-44—4,000)—30169 375-A

Figure 140. FAS Form 9.

AZIMUTH BY A STAR, HOUR-ANGLE METHOD

Set up at...

Star S...

Mark...

Date...

Latitude Φ...

Longitude...

Time Zone...

Watch F(−) or S(+) ....Seconds

Watch Checked Against...

Locality...

Weather...

Observer...

Recorder...

Instrument No...

Greenwich Date...

Tel.	Rep.	Time hr	Time min	Time sec	Horizontal Angle °	Horizontal Angle ′	Verniers ″ A	Verniers ″ B	Verniers ″ Mn.
D	0	—	—	—	0	00	00		
D	1							—	—
D	2				—	—	—	—	—
D	3							—	—
R	4				—	—	—	—	—
R	5				—	—	—	—	—
R	6								
							—	—	
	Mean						—	—	

	hr	min	sec
Watch Corr			
Time Zone Corr			
(1) GCT			
(2) Greenwich Sidereal Time at 0 GCT (Ephemeris)			
(3) Correction, Mean Solar Time to Sidereal Time of Observation (Table III, Ephemeris)			
(4) Greenwich Sidereal Time of Observation (1) + (2) + (3)			
(5) Longitude W(−) E(+) (in hr, min, sec)			
(6) Local Sidereal Time (4) + (5)			
(7) Right Ascension of Star (Ephemeris)			
(8) Local Hour Angle of Star (6) − (7)			

SKETCH

True North

Observer

Declination δ of Star (Ephemeris) = ____ ° ′ ″

t = Equivalent of (8) in deg, min, sec = ____ ° ′ ″ Φ = ____ ° ′ ″

Log Tan δ......................... Log Cos t......................... Log Sin t.........................

Log Cos Φ......................... Log Sin Φ......................... Log (a − b).........................

Sum = Log a......................... Sum = Log b......................... Diff. = Log Tan A.........................

a......................... b......................... A.........................

b.........................

a − b.........................

$$\text{Tan A} = \frac{\text{Sin t}}{\text{Cos}\,\Phi\,\text{Tan}\,\delta - \text{Sin}\,\Phi\,\text{Cos t}} = \frac{\text{Sin t}}{\text{a} - \text{b}}$$

A = Azimuth of Star S East (A+) or West (A−) of True North.

	°	′	″
Azimuth to Star.........			
Minus Angle, Mark to Star.........			
True Azimuth to Mark.........			
Grid Correction.........			
Grid Azimuth to Mark.........			

INSTRUCTIONS

See TM 5-235 Paragraph 178c.

Check Signs and Quadrants by use of Sketch.

Computed by ____________________ Date of Computation ____________________

FAS Form No. 10

FAS, Fort Sill, Okla., (10-2-44—4,000)—30170 375-A

Figure 141. FAS Form 10.

AZIMUTH BY SUN OR A STAR, ALTITUDE METHOD

	Tel.	Object	Time			Horizontal Angle			Vertical Angle		
Set up at											
Celestial Body S			hr	min	sec	°	′	″	°	′	″
Mark	D	Mark	—	—	—	0	00	00	—	—	—
Date	D	+ Apparent Sun Position									—
Latitude Φ	D	+									—
Longitude	D	+									—
Time Zone	R	+									—
Watch F(−) or S(+) .... Seconds	R	+									—
Watch Checked Against	R	+									—
Locality	R	Mark	—	—	—				—	—	—
Weather		Mean									
Temperature		Watch Corr				Parallax + (sun only)					
Instrument No.		Time Zone Corr				Refraction −					
Greenwich Date		GCT				Altitude h					

	°	′	″
Declination δ at 0ʰ GCT ±			
GCT × δ Variation per hr ±			
Corrected Declination δ ±			

Observer..............................

Recorder..............................

$p = 90° - \delta$ $\qquad s = \frac{1}{2}(p + \Phi + h)$

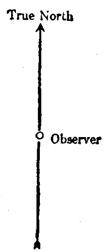
A = Azimuth of S East or West of True North

$$\text{Tan } \tfrac{1}{2} A = \sqrt{\frac{\text{Sin }(s-\Phi)\ \text{Sin }(s-h)}{\text{Cos } s\ \text{Cos }(s-p)}}$$

	°	′	″		
p					
Φ					
h					
Sum 2)					
s				Colog Cos	
s − p				Colog Cos	
s − Φ				Log Sin	
s − h				Log Sin	
				Sum 2)	
				Log Tan ½ A	

	°	′	″
½ A			
A (E or W of North)			
Azimuth to S			
Minus Angle, Mark to S			
True Azimuth to Mark			
Grid Correction			
Grid Azimuth to Mark			

Sketch



Computed by ______________________ Date of Computation ______________________

FAS Form No. 11

FAS, Fort Sill, Okla., (9-7-44—3,000)—800:0 875-A

Figure 142. FAS Form 11.

Section VII. CONVERSION FACTORS AND CONVERSION TABLES

156. CONVERSION FACTORS.

To convert	To	Multiply by	Logarithm
Degrees (angle)	Grads	1.1111111	0.045 7575
Degrees	Mils	17.777778	1.249 8775
Feet	Meters	0.30480061	9.484 0158
Feet	Miles	0.00018939	6.277 3661
Feet	Sound Seconds	0.00090285	6.955 6171
Gallons (Imperial)	Gallons (U. S.)	1.2009	0.079 5219
Gallons (U. S.)	Gallons (Imperial)	0.83268	9.920 4781
Gallons	Liters	3.7853	0.578 1040
Gallons	Ounces (fluid)	128	2.107 2100
Gallons	Pints	8	0.903 0900
Grads	Degrees	0.9	9.954 2425
Grads	Mils	16	1.204 1200
Grads	Minutes	54	1.732 3938
Grads	Seconds	3240	3.510 5450
Grams	Ounces (Av.)	0.035274	8.547 4537
Grams	Pounds (Av.)	0.0022046	7.343 3337
Inches	Millimeters	25.400	1.404 8346
Inches of mercury	Millibars	33.864	1.529 7377
Liters	Gallons (U. S.)	0.26418	9.421 9860
Liters	Ounces (fluid)	33.815	1.529 1060
Liters	Pints	2.1134	0.324 9860
Meters	Feet	3.2808333	0.515 9842
Meters	Miles	0.00062137	6.793 3502
Meters	Sound seconds	0.0029621	7.471 6012
Meters	Yards	1.0936111	0.038 8629
Meters per second	Miles per hour	2.2369	0.349 6527
Miles	Feet	5280	3.722 6339
Miles	Meters	1609.3	3.206 6498
Miles	Sound seconds	4.7671	0.678 2510
Miles	Yards	1760	3.245 5127
Miles per hour	Meters per second	0.44704	9.650 3473
Miles	Yards per second	0.48889	9.689 2102
Millibars	Inches of mercury	0.029530	8.470 2623
Millibars	Millimeters of mercury	0.75006	9.875 0969
Millimeters	Inches	0.03937	8.595 1654

To convert	To	Multiply by	Logarithm
Millimeters of mercury	Millibars........	1.3332	0.124 9031
Mils............	Degrees..........	0.05625	8.750 1225
Mils............	Grads............	0.0625	8.795 8800
Mils............	Minutes..........	3.375	0.528 2738
Mils............	Seconds..........	202.5	2.306 4250
Minutes (angle)..	Grads............	0.018518519	8.267 6062
Minutes..........	Mils.............	0.29629630	9.471 7262
Ounces (weight, Av.)	Grams..........	28.350	1.452 5463
Ounces (fluid)....	Gallons..........	0.0078125	7.892 7900
Ounces..........	Liters...........	0.029573	8.470 8940
Ounces..........	Pints............	0.0625	8.795 8800
Pints............	Gallons..........	0.125	9.096 9100
Pints............	Liters...........	0.47317	9.675 0140
Pints............	Ounces (fluid)....	16	1.204 1200
Pounds (Av.).....	Grams..........	453.59	2.656 6663
Seconds (angle)...	Grads...........	0.00030864198	6.489 4550
Seconds..........	Mils............	0.0049382716	7.693 5750
Sound seconds....	Feet............	1107.6	3.044 3829
Sound..........	Meters..........	337.60	2.528 3988
Sound..........	Miles...........	0.20977	9.321 7490
Sound..........	Yards...........	369.2	2.567 2617
Yards..........	Meters..........	0.91440183	9.961 1371
Yards..........	Miles...........	0.00056818	6.754 4873
Yards..........	Sound seconds...	0.0027086	7.432 7383
Yards per second.	Miles per hour...	2.0455	0.310 7898

157. MILS TO DEGREES, MINUTES AND SECONDS.

Hundreds of mils

Mils	Degrees	Mils	Degrees	Mils	Degrees
100	05° 37′ 30″	800	45° 00′ 00″	1,500	84° 22′ 30″
200	11° 15′ 00″	900	50° 37′ 30″	1,600	90° 00′ 00″
300	16° 52′ 30″	1,000	56° 15′ 00″		
400	22° 30′ 00″	1,100	61° 52′ 30″	3,200	180° 00′ 00″
500	28° 07′ 30″	1,200	67° 30′ 00″	4,800	270° 00′ 00″
600	33° 45′ 00″	1,300	73° 07′ 30″	6,400	360° 00′ 00″
700	39° 22′ 30″	1,400	78° 45′ 00″		

Mils	Degrees	Mils	Degrees	Mils	Degrees
1	00° 03′ 22″	36	02° 01′ 30″	71	03° 59′ 38″
2	00° 06′ 45″	37	02° 04′ 52″	72	04° 03′ 00″
3	00° 10′ 08″	38	02° 08′ 15″	73	04° 06′ 22″
4	00° 13′ 30″	39	02° 11′ 38″	74	04° 09′ 45″
5	00° 16′ 52″	40	02° 15′ 00″	75	04° 13′ 08″
6	00° 20′ 15″	41	02° 18′ 22″	76	04° 16′ 30″
7	00° 23′ 38″	42	02° 21′ 45″	77	04° 19′ 52″
8	00° 27′ 00″	43	02° 25′ 08″	78	04° 23′ 15″
9	00° 30′ 22″	44	02° 28′ 30″	79	04° 26′ 38″
10	00° 33′ 45″	45	02° 31′ 52″	80	04° 30′ 00″
11	00° 37′ 08″	46	02° 35′ 15″	81	04° 33′ 22″
12	00° 40′ 30″	47	02° 38′ 38″	82	04° 36′ 45″
13	00° 43′ 52″	48	02° 42′ 00″	83	04° 40′ 08″
14	00° 47′ 15″	49	02° 45′ 22″	84	04° 43′ 30″
15	00° 50′ 38″	50	02° 48′ 45″	85	04° 46′ 52″
16	00° 54′ 00″	51	02° 52′ 08″	86	04° 50′ 15″
17	00° 57′ 22″	52	02° 55′ 30″	87	04° 53′ 38″
18	01° 00′ 45″	53	02° 58′ 52″	88	04° 57′ 00″
19	01° 04′ 08″	54	03° 02′ 15″	89	05° 00′ 22″
20	01° 07′ 30″	55	03° 05′ 38″	90	05° 03′ 45″
21	01° 10′ 52″	56	03° 09′ 00″	91	05° 07′ 08″
22	01° 14′ 15″	57	03° 12′ 22″	92	05° 10′ 30″
23	01° 17′ 38″	58	03° 15′ 45″	93	05° 13′ 52″
24	01° 21′ 00″	59	03° 19′ 08″	94	05° 17′ 15″
25	01° 24′ 22″	60	03° 22′ 30″	95	05° 20′ 38″
26	01° 27′ 45″	61	03° 25′ 52″	96	05° 24′ 00″
27	01° 31′ 08″	62	03° 29′ 15″	97	05° 27′ 22″
28	01° 34′ 30″	63	03° 32′ 38″	98	05° 30′ 45″
29	01° 37′ 52″	64	03° 36′ 00″	99	05° 34′ 08″
30	01° 41′ 15″	65	03° 39′ 22″	100	05° 37′ 30″
31	01° 44′ 38″	66	03° 42′ 45″		
32	01° 48′ 00″	67	03° 46′ 08″		
33	01° 51′ 22″	68	03° 49′ 30″		
34	01° 54′ 45″	69	03° 52′ 52″		
35	01° 58′ 08″	70	03° 56′ 15″		

Tenths and hundreths

Mils	Degrees	Mils	Degrees	Mils	Degrees
0.01	00° 00′ 02″	0.36	00° 01′ 13″	0.71	00° 02′ 24″
0.02	00° 00′ 04″	0.37	00° 01′ 15″	0.72	00° 02′ 26″
0.03	00° 00′ 06″	0.38	00° 01′ 17″	0.73	00° 02′ 28″
0.04	00° 00′ 08″	0.39	00° 01′ 19″	0.74	00° 02′ 30″
0.05	00° 00′ 10″	0.40	00° 01′ 21″	0.75	00° 02′ 32″
0.06	00° 00′ 12″	0.41	00° 01′ 23″	0.76	00° 02′ 34″
0.07	00° 00′ 14″	0.42	00° 01′ 25″	0.77	00° 02′ 36″
0.08	00° 00′ 16″	0.43	00° 01′ 27″	0.78	00° 02′ 38″
0.09	00° 00′ 18″	0.44	00° 01′ 29″	0.79	00° 02′ 40″
0.10	00° 00′ 20″	0.45	00° 01′ 31″	0.80	00° 02′ 42″
0.11	00° 00′ 22″	0.46	00° 01′ 33″	0.81	00° 02′ 44″
0.12	00° 00′ 24″	0.47	00° 01′ 35″	0.82	00° 02′ 46″
0.13	00° 00′ 26″	0.48	00° 01′ 37″	0.83	00° 02′ 48″
0.14	00° 00′ 28″	0.49	00° 01′ 39″	0.84	00° 02′ 50″
0.15	00° 00′ 30″	0.50	00° 01′ 41″	0.85	00° 02′ 52″
0.16	00° 00′ 32″	0.51	00° 01′ 43″	0.86	00° 02′ 54″
0.17	00° 00′ 34″	0.52	00° 01′ 45″	0.87	00° 02′ 56″
0.18	00° 00′ 36″	0.53	00° 01′ 47″	0.88	00° 02′ 58″
0.19	00° 00′ 38″	0.54	00° 01′ 49″	0.89	00° 03′ 00″
0.20	00° 00′ 40″	0.55	00° 01′ 51″	0.90	00° 03′ 02″
0.21	00° 00′ 43″	0.56	00° 01′ 53″	0.91	00° 03′ 04″
0.22	00° 00′ 45″	0.57	00° 01′ 55″	0.92	00° 03′ 06″
0.23	00° 00′ 47″	0.58	00° 01′ 57″	0.93	00° 03′ 08″
0.24	00° 00′ 49″	0.59	00° 01′ 59″	0.94	00° 03′ 10″
0.25	00° 00′ 51″	0.60	00° 02′ 02″	0.95	00° 03′ 12″
0.26	00° 00′ 53″	0.61	00° 02′ 04″	0.96	00° 03′ 14″
0.27	00° 00′ 55″	0.62	00° 02′ 06″	0.97	00° 03′ 16″
0.28	00° 00′ 57″	0.63	00° 02′ 08″	0.98	00° 03′ 18″
0.29	00° 00′ 59″	0.64	00° 02′ 10″	0.99	00° 03′ 20″
0.30	00° 01′ 01″	0.65	00° 02′ 12″	1.00	00° 03′ 22″
0.31	00° 01′ 03″	0.66	00° 02′ 14″		
0.32	00° 01′ 05″	0.67	00° 02′ 16″		
0.33	00° 01′ 07″	0.68	00° 02′ 18″		
0.34	00° 01′ 09″	0.69	00° 02′ 20″		
0.35	00° 01′ 11″	0.70	00° 02′ 22″		

158. DEGREES, MINUTES, AND SECONDS TO MILS.

Degrees to mils

Degrees	Mils	Degrees	Mils	Degrees	Mils
1	17.78	36	640.00	71	1,262.22
2	35.56	37	657.78	72	1,280.00
3	53.33	38	675.56	73	1,297.78
4	71.11	39	693.33	74	1,315.56
5	88.89	40	711.11	75	1,333.33
6	106.67	41	728.89	76	1,351.11
7	124.44	42	746.67	77	1,368.89
8	142.22	43	764.44	78	1,386.67
9	160.00	44	782.22	79	1,404.44
10	177.79	45	800.00	80	1,422.22
11	195.56	46	817.78	81	1,440.00
12	213.33	47	835.56	82	1,457.78
13	231.11	48	853.33	83	1,475.56
14	248.89	49	871.11	84	1,493.33
15	266.67	50	888.89	85	1,511.11
16	284.44	51	906.67	86	1,528.89
17	302.22	52	924.44	87	1,546.67
18	320.00	53	942.22	88	1,564.44
19	337.78	54	960.00	89	1,582.22
20	355.56	55	977.78	90	1,600.00
21	373.33	56	995.56		
22	391.11	57	1,013.33		
23	408.89	58	1,031.11		
24	426.67	59	1,048.89		
25	444.44	60	1,066.67		
26	462.22	61	1,084.44		
27	480.00	62	1,102.22		
28	497.78	63	1,120.00	180	3,200.00
29	515.56	64	1,137.78	270	4,800.00
30	533.33	65	1,155.56	360	6,400.00
31	551.11	66	1,173.33		
32	568.89	67	1,191.11		
33	586.67	68	1,208.89		
34	604.44	69	1,226.67		
35	622.22	70	1,244.44		

Minutes to mils

Minutes	Mils	Minutes	Mils	Minutes	Mils
1	0.30	21	6.22	41	12.15
2	0.59	22	6.52	42	12.44
3	0.89	23	6.81	43	12.74
4	1.19	24	7.11	44	13.04
5	1.48	25	7.41	45	13.33
6	1.78	26	7.70	46	13.63
7	2.07	27	8.00	47	13.93
8	2.37	28	8.30	48	14.22
9	2.67	29	8.59	49	14.52
10	2.96	30	8.89	50	14.81
11	3.26	31	9.19	51	15.11
12	3.56	32	9.48	52	15.41
13	3.85	33	9.78	53	15.70
14	4.15	34	10.07	54	16.00
15	4.44	35	10.37	55	16.30
16	4.74	36	10.67	56	16.59
17	5.04	37	10.96	57	16.89
18	5.33	38	11.26	58	17.19
19	5.63	39	11.56	59	17.48
20	5.93	40	11.85	60	17.78

Seconds to mils

Seconds	Mils	Seconds	Mils	Seconds	Mils
2	0.01	22	0.11	42	0 21
4	0.02	24	0.12	44	0.22
6	0.03	26	0.13	46	0.23
8	0.04	28	0.14	48	0.24
10	0.05	30	0.15	50	0.25
12	0.06	32	0.16	52	0.26
14	0.07	34	0.17	54	0.27
16	0.08	36	0.18	56	0.28
18	0.09	38	0.19	58	0.29
20	0.10	40	0.20	60	0.30

159. YARDS TO METERS.

Yards	Meters	Yards	Meters	Yards	Meters
100	91.44	3,600	3,291.85	7,100	6,492.25
200	182.88	3,700	3,383.29	7,200	6,583.69
300	274.32	3,800	3,474.73	7,300	6,675.13
400	365.76	3,900	3,566.17	7,400	6,766.57
500	457.20	4,000	3,657.61	7.500	6,858.01
600	548.64	4,100	3,749.05	7,600	6,949.45
700	640.08	4,200	3,840.49	7,700	7,040.89
800	731.52	4,300	3,931.93	7,800	7,132.33
900	822.96	4,400	4,023.37	7,900	7,223.77
1,000	914.40	4,500	4,114.81	8,000	7,315.21
1,100	1,005.84	4,600	4,206.25	8,100	7,406.65
1,200	1,097.28	4.700	4,297.69	8,200	7,498.09
1,300	1,188.72	4,800	4,389.13	8,300	7,589.54
1,400	1,280.16	4,900	4,480.57	8,400	7,680.98
1,500	1,371.60	5,000	4,572.01	8,500	7,772.42
1,600	1,463.04	5,100	4,663.45	8,600	7,863.86
1,700	1,554.48	5,200	4,754.89	8,700	7,955.30
1,800	1,645.92	5,300	4,846.33	8,800	8,046.74
1,900	1,737.36	5,400	4,937.77	8,900	8,138.18
2,000	1,828.80	5,500	5,029.21	9,000	8,229.62
2,100	1,920.24	5,600	5,120.65	9,100	8,321.06
2,200	2,011.68	5,700	5,212.09	9,200	8,412.50
2,300	2,103.12	5,800	5,303.53	9,300	8,503.94
2,400	2,194.56	5,900	5,394.97	9,400	8,595.38
2,500	2,286.00	6,000	5,486.41	9,500	8,686.82
2,600	2,377.44	6,100	5,577.85	9,600	8,778.26
2,700	2,468.88	6,200	5,669.29	9,700	8,869.70
2,800	2,560.33	6,300	5,760.73	9,800	8,961.14
2,900	2,651.77	6,400	5,852.17	9,900	9,052.58
3,000	2,743.21	6,500	5,943.61	10,000	9,144.02
3,100	2,834.65	6,600	6,035.05		
3,200	2,926.09	6,700	6,126.49		
3,300	3,017.53	6,800	6,217.93		
3,400	3,108.97	6,900	6,309.37		
3,500	3,200.41	7,000	6,400.81		

Example: Find the number of meters corresponding to 7,391.40 yards.

7,300	yards =	6,675.13 meters
91	yards =	83.21 meters
0.40	yards =	0.37 meters
7,391.40	yards =	6,758.71 meters

160. METERS TO YARDS.

Meters	Yards	Meters	Yards	Meters	Yards
100	109.36	3,600	3,937.00	7,100	7,764.64
200	218.72	3,700	4,046.36	7,200	7,874.00
300	328.08	3,800	4,155.72	7,300	7,983.36
400	437.44	3,900	4,265.08	7,400	8,092.72
500	546.81	4,000	4,374.44	7,500	8,202.08
600	656.17	4,100	4,483.81	7,600	8,311.44
700	765.53	4,200	4,593.17	7,700	8,420.81
800	874.89	4,300	4,702.53	7,800	8,530.17
900	984.25	4,400	4,811.89	7,900	8,639.53
1,000	1,093.61	4,500	4,921.25	8,000	8,748.89
1,100	1,202.97	4,600	5,030.61	8,100	8,858.25
1,200	1,312.33	4,700	5,139.97	8,200	8,967.61
1,300	1,421.69	4,800	5,249.33	8,300	9,076.97
1,400	1,531.06	4,900	5,358.69	8,400	9,186.33
1,500	1,640.42	5,000	5,468.06	8,500	9.295.69
1,600	1,749.78	5,100	5,577.42	8,600	9,405.06
1,700	1,859.14	5,200	5,686.78	8,700	9.514.42
1,800	1,968.50	5,300	5,796.14	8,800	9,623.78
1,900	2,077.86	5,400	5,905.50	8,900	9,733.14
2,000	2,187.22	5,500	6,014.86	9,000	9,842.50
2,100	2,296.58	5,600	6,124.22	9,100	9,951.86
2,200	2,405.95	5,700	6,233.58	9,200	10,061.22
2,300	2,515.31	5,800	6,342.94	9,300	10,170.58
2,400	2,624.67	5,900	6,452.31	9,400	10,279.94
2,500	2,734.03	6,000	6,561.67	9,500	10,389.31
2,600	2,843.39	6,100	6,671.03	9,600	10,498.67
2,700	2,952.75	6,200	6,780.39	9,700	10,608.03
2,800	3,062.11	6,300	6,889.75	9,800	10,717.39
2,900	3,171.47	6,400	6,999.11	9,900	10,826.75
3,000	3,280.83	6,500	7,108.47	10,000	10,936.11
3,100	3,390.19	6,600	7,217.83		
3,200	3,499.56	6,700	7,327.19		
3,300	3,608.92	6,800	7,436.56		
3,400	3,718.28	6,900	7,545.92		
3,500	3,827.64	7,000	7,655.28		

Example: Find the number of yards corresponding to 6758.71 meters.

6,700	meters =	7,327.19	yards
58	meters =	63.43	yards
0.71	meters =	0.78	yards
6,758.71	meters =	7,391.40	yards

161: YARDS TO SOUND SECONDS.

Yards	Seconds	Yards	Seconds	Yards	Seconds
100	0.271	3,600	9.751	7,100	19.231
200	0.542	3,700	10.022	7,200	19.502
300	0.813	3,800	10.293	7,300	19.772
400	1.083	3,900	10.563	7,400	20.043
500	1.354	4,000	10.834	7,500	20.314
600	1.625	4,100	11.105	7,600	20.585
700	1.896	4,200	11.376	7,700	20.856
800	2.167	4,300	11.647	7,800	21.127
900	2.438	4,400	11.918	7,900	21.398
1,000	2.709	4,500	12.189	8,000	21.668
1,100	2.979	4,600	12.459	8,100	21.939
1,200	3.250	4,700	12.730	8,200	22.210
1,300	3.521	4,800	13.001	8,300	22.481
1,400	3.792	4,900	13.272	8,400	22.752
1,500	4.063	5,000	13.543	8,500	23.023
1,600	4.334	5,100	13.814	8,600	23.294
1,700	4.605	5,200	14,085	8,700	23.564
1,800	4.875	5,300	14.355	8,800	23.835
1,900	5.146	5,400	14.626	8,900	24.106
2,000	5.417	5,500	14.897	9,000	24.377
2,100	5.688	5,600	15.168	9,100	24.648
2,200	5.959	5,700	15.439	9,200	24.919
2,300	6.230	5,800	15.710	9,300	25.190
2,400	6.501	5,900	15.980	9,400	25.460
2,500	6.771	6,000	16.251	9,500	25.731
2,600	7.042	6,100	16.522	9,600	26.002
2,700	7.313	6,200	16.793	9,700	26.273
2,800	7.584	6,300	17.064	9,800	26.544
2,900	7.855	6,400	17,335	9,900	26.815
3,000	8.126	6,500	17.606	10,000	27.086
3,100	8.397	6,600	17.876		
3,200	8.667	6,700	18.147		
3,300	8.938	6,800	18.418		
3,400	9.209	6,900	18.689		
3,500	9.480	7,000	18.960		

Example: Find the number of sound seconds corresponding to 4485.4 yards.

4,400	yards =	11.918	seconds
85	yards =	0.230	seconds
0.4	yards =	0.001	seconds
4,485.4	yards =	12.149	seconds

162. SOUND SECONDS TO YARDS.

Note.—To find the distance which sound travels in a given time under other than standard atmospheric conditions, the time interval must first be corrected to standard conditions.

Seconds	Yards	Seconds	Yards	Seconds	Yards
0.1	36.9	3.6	1,329.1	7.1	2,621.3
0.2	73.8	3.7	1,366.0	7.2	2,658.2
0.3	110.8	3.8	1,403.0	7.3	2,695.2
0.4	147.7	3.9	1,439.9	7.4	2,732.1
0.5	184.6	4.0	1,476.8	7.5	2,769.0
0.6	221.5	4.1	1,513.7	7.6	2,805.9
0.7	258.4	4.2	1,550.6	7.7	2,842.8
0.8	295.4	4.3	1,587.6	7.8	2,879.8
0.9	332.3	4.4	1,624.5	7.9	2,916.7
1.0	369.2	4.5	1,661.4	8.0	2,953.6
1.1	406.1	4.6	1,698.3	8.1	2,990.5
1.2	443.0	4.7	1,735.2	8.2	3,027.4
1.3	480.0	4.8	1,772.2	8.3	3,064.4
1.4	516.9	4.9	1,809.1	8.4	3,101.3
1.5	553.8	5.0	1,846.0	8.5	3,138.2
1.6	590.7	5.1	1,882.9	8.6	3,175.1
1.7	627.6	5.2	1,919.8	8.7	3,212.0
1.8	664.6	5.3	1,956.8	8.8	3,249.0
1.9	701.5	5.4	1,993.7	8.9	3,285.9
2.0	738.4	5.5	2,030.6	9.0	3,322.8
2.1	775.3	5.6	2,067.5	9.1	3,359.7
2.2	812.2	5.7	2,104.4	9.2	3,396.6
2.3	849.2	5.8	2,141.4	9.3	3,433.6
2.4	886.1	5.9	2,178.3	9.4	3,470.5
2.5	923.0	6.0	2,215.2	9.5	3,507.4
2.6	959.9	6.1	2,252.1	9.6	3,544.3
2.7	996.8	6.2	2,289.0	9.7	3,581.2
2.8	1,033.8	6.3	2,326.0	9.8	3,618.2
2.9	1,070.7	6.4	2,362.9	9.9	3,655.1
3.0	1,107.6	6.5	2,399.8	10.0	3,692.0
3.1	1,144.5	6.6	2,436.7		
3.2	1,181.4	6.7	2,473.6		
3.3	1,218.4	6.8	2,510.6		
3.4	1,255.3	6.9	2,547.5		
3.5	1,292.2	7.0	2,584.4		

Example: Find the distance in yards corresponding to 12.149 sound seconds.

10 seconds	=	3,692.0 yards
2.1 seconds	=	775.3 yards
0.049 seconds	=	18.1 yards
12.149 seconds	=	4,485.4 yards

163. METERS TO SOUND SECONDS.

Meters	Seconds	Meters	Seconds	Meters	Seconds
100	0.296	3,600	10.664	7,100	21,031
200	0.592	3,700	10.960	7,200	21,327
300	0.889	3,800	11.256	7,300	21,623
400	1.185	3,900	11.552	7,400	21,920
500	1.481	4,000	11.848	7,500	22,216
600	1.777	4,100	12.145	7,600	22,512
700	2.073	4,200	12.441	7,700	22,808
800	2.370	4,300	12.737	7,800	23,104
900	2.666	4,400	13.033	7,900	23,401
1,000	2.962	4,500	13.329	8,000	23,697
1,100	3.258	4,600	13.626	8,100	23,993
1,200	3.555	4,700	13.922	8,200	24,289
1,300	3.851	4,800	14.218	8,300	24,586
1,400	4.147	4,900	14.514	8,400	24,882
1,500	4.443	5,000	14.811	8,500	25,178
1,600	4.739	5,100	15,107	8,600	25,474
1,700	5.036	5,200	15,403	8,700	25,770
1,800	5.332	5,300	15,699	8,800	26,067
1,900	5.628	5,400	15,995	8,900	26,363
2,000	5.924	5,500	16,292	9,000	26,659
2,100	6.220	5,600	16,588	9,100	26,955
2,200	6.517	5,700	16,884	9,200	27,251
2,300	6.813	5,800	17,180	9,300	27,548
2,400	7.109	5,900	17,476	9,400	27,844
2,500	7.405	6,000	17,773	9,500	28,140
2,600	7.701	6,100	18,069	9,600	28,436
2,700	7.998	6,200	18,365	9,700	28,732
2,800	8.294	6,300	18,661	9,800	29,029
2,900	8.590	6,400	18,958	9,900	29,325
3,000	8.886	6,500	19,254	10,000	29,621
3,100	9.183	6,600	19,550		
3,200	9.479	6,700	19,846		
3,300	9.775	6,800	20,142		
3,400	10.071	6,900	20,439		
3,500	10.367	7,000	20,735		

Example: Find the number of sound seconds corresponding to 4,101.5 meters.

4,100	meters =	12.145	seconds
01	meters =	0.003	seconds
0.5	meters =	0.001	seconds
4,101.5	meters =	12.149	seconds

164. SOUND SECONDS TO METERS.

Note.—To find the distance which sound travels in a given time under other than standard atmospheric conditions, the time interval must first be corrected to standard conditions.

Seconds	Meters	Seconds	Meters	Seconds	Meters
0.1	33.8	3.6	1,215.3	7.1	2,396.9
0.2	67.5	3.7	1,249.1	7.2	2,430.7
0.3	101.3	3.8	1,282.9	7.3	2,464.5
0.4	135.0	3.9	1,316.6	7.4	2,498.2
0.5	168.8	4.0	1,350.4	7.5	2,532.0
0.6	202.6	4.1	1,384.1	7.6	2,565.7
0.7	236.3	4.2	1,417.9	7.7	2,599.5
0.8	270.1	4.3	1,451.7	7.8	2,633.3
0.9	303.8	4.4	1,485.4	7.9	2,667.0
1.0	337.6	4.5	1,519.2	8.0	2,700.8
1.1	371.4	4.6	1,552.9	8.1	2,734.5
1.2	405.1	4.7	1,586.7	8.2	2,768.3
1.3	438.9	4.8	1,620.5	8.3	2,802.1
1.4	472.6	4.9	1,654.2	8.4	2,835.8
1.5	506.4	5.0	1,688.0	8.5	2,869.6
1.6	540.2	5.1	1,721.7	8.6	2,903.3
1.7	573.9	5.2	1,755.5	8.7	2,937.1
1.8	607.7	5.3	1,789.3	8.8	2,970.9
1.9	641.4	5.4	1,823.0	8.9	3,004.6
2.0	675.2	5.5	1,856.8	9.0	3,038.4
2.1	709.0	5.6	1,890.5	9.1	3,072.1
2.2	742.7	5.7	1,924.3	9.2	3,105.9
2.3	776.5	5.8	1,958.1	9.3	3,139.7
2.4	810.2	5.9	1,991.8	9.4	3,173.4
2.5	844.0	6.0	2,025.6	9.5	3,207.2
2.6	877.8	6.1	2,059.3	9.6	3,240.9
2.7	911.5	6.2	2,093.1	9.7	3,274.7
2.8	945.3	6.3	2,126.9	9.8	3,308.5
2.9	979.0	6.4	2,160.6	9.9	3,342.2
3.0	1,012.8	6.5	2,194.4	10.0	3,376.0
3.1	1,046.6	6.6	2,228.1		
3.2	1,080.3	6.7	2,261.9		
3.3	1,114.1	6.8	2,295.7		
3.4	1,147.8	6.9	2,329.4		
3.5	1,181.6	7.0	2,363.2		

Example: Find the distance in meters corresponding to 12.149 sound seconds.

10	seconds =	3,376.0	meters
2.1	seconds =	709.0	meters
0.049	seconds =	16.5	meters
12.149	seconds =	4,101.5	meters

Section VIII. APPEARANCE OF OBJECTS AT DIFFERENT DISTANCES

165. APPEARANCE OF OBJECTS AT DIFFERENT DISTANCES. a. An object appears nearer—

(1) When looking over water, or over a large ravine or depression.

(2) When the sun is behind the observer.

(3) When air is clear, especially after a rain.

(4) When the background is in contrast with the color of the object.

(5) When using field glasses.

(6) When trees are leafless, as in winter.

(7) When trees or branches are silhouetted against a clear skyline or contrasting background.

b. An object appears more distant—

(1) When looking over rolling country.

(2) When the sun is in front of the observer.

(3) When air is not clear due to fog, smoke, rain, etc.

(4) When background is similar in color to that of an object.

(5) On hot days, especially when the ground is moist, an object will appear more distant if observed from a kneeling or sitting position. (Due to heat radiation.)

c. **Distance and visibility table.**

Range in yards	Trees	Troops	Buildings
1,000	Minor branches distinguishable. Foliage blends into clusterlike shape with sky as background; daylight can be seen through the branches.		
1,200		Infantry column can be distinguished.	Sign posts and national insignias distinguishable.
1,500	Foliage densely clustered, presenting a rough surface. Outlines of large branch or group of branches distinguishable.	Dismounted, in small masses; mounted, outlines of horses become distinguishable. Vehicles in column distinguishable.	
3,000	Lower half of trunks visible; main branches blend with foliage.	Truck columns and horse-drawn artillery can be distinguished.	
4,000	Trunks blend with foliage; surface of clusters smooth.		Ordinary houses distinguishable.
5,000	Entire area covered by trees appears like a bushy area at about 100 yards, except that surface is smoother and blacker.		Ordinary factory chimneys and steel water towers become distinguishable.
16,000			Churches, castles, and prominent buildings distinguishable.

Section IX. CURVATURE AND REFRACTION TABLES

166. CURVATURE AND REFRACTION TABLES. The corrections in the table are always to be added to the altitude of the point as determined from the vertical angle from a station of known altitude.

Range (yards)	Correction (feet)	Range (yards)	Correction (feet)
1,000	.2	16,000	47.3
2,000	.7	17,000	53.4
3,000	1.7	18,000	59.8
4,000	3.0	19,000	66.7
5,000	4.6	20,000	73.9
6,000	6.6	21,000	81.4
7,000	9.0	22,000	98.6
8,000	11.8	23,000	97.7
9,000	15.0	24,000	106.4
10,000	18.5	25,000	115.4
11,000	22.3	26,000	124.8
12,000	26.6	27,000	134.6
13,000	31.2	28,000	144.8
14,000	36.2	29,000	155.3
15,000	41.6	30,000	166.2

Formula: $H = K \times .1847$

H in feet

K in thousands of yards (that is, 10,000 yards, $K = 10$)

Note.—The correction may be neglected when the range is less than 5,000 yards.

Section X. FORMULAE FOR PHOTOGRAPHIC SOLUTIONS

167. FORMULAE FOR PHOTOGRAPHIC SOLUTIONS.

a. For temperature above 60° F. For the best photographic results, the solutions should be kept at a temperature above 60° F., when developing and fixing.

(1) *Developer.*

"A" solution

Sodium sulphite, anhydrous	150 grams
Hydroquinone	24 grams
Elon	42 grams
Water	90 ounces

"B" solution

Sodium hydroxide	76 grams
Water	50 ounces

Note.—These solutions may be made up and kept for a period of 2 weeks in brown glass bottles. They should be kept separate until just before using. Use 10 parts of "B" solution to 18 parts of "A" solution for normal developing. To speed up developing, the proportion of "B" solution is slightly increased. As the temperature of the solution increases, the proportion of "B" solution may be reduced.

(2) *Fixing solution:*

Sodium hyposulphite (hypo)	800 grams
Ammonium chloride	50 grams
Water	75 ounces

Two tablespoons of acetic acid in the fixing tray will aid the fixation.

b. For temperature below 60° F. For temperature below 60° F., the following solutions should be used.

(1) *Developer.*

"A" solution

Sodium sulphite, anhydrous............................	175 grams
Hydroquinone	30 grams
Elon	80 grams
Water	90 ounces

"B" solution

Sodium hydroxide	100 grams
Water	50 ounces

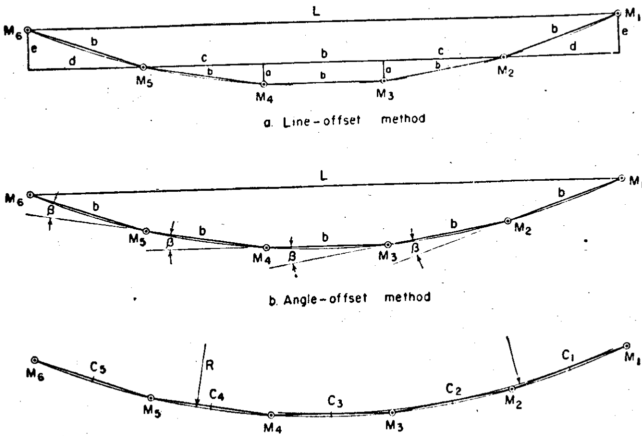
(2) *Fixing solution:*

Sodium hyposulphite (hypo)	1,500 grams
Ammonium chloride	50 grams
Water	1 gallon

Use 18 parts of the "A" solution to 10 parts of "B" solution.

Section XI. SURVEY AND COMPUTATION TABLES FOR CURVED BASE

168. SURVEY AND COMPUTATION TABLES FOR CURVED BASE.



M_1, M_2, etc.– Microphone positions
C_1, C_2, etc.– Microphone of sub-boses
s = Length of sub-base (sound seconds)
b = Length of sub-bases (yards)
a, c, d, e = Distonces in yards
L = Length of long chord (M_1 to M_6)
β = Angular offset between adjacent sub-bases
r = Radius of arc possing through midpoints
R = Radius of arc passing through microphones
Center of curvature – Center of arcs on which microphones and midpoints lie; this is also the point where the perpendicular bisectors of the sub-bases converge.

Figure 143. Elements of curved sound ranging bases.

Table A

s Sound seconds	r Sound seconds	b Yards	log b	r Yards	log r	$\frac{\beta}{2}$ °	$\frac{\beta}{2}$ ′	$\frac{\beta}{2}$ ″	β °	β ′	β ″	2β °	2β ′	2β ″
3.5	25	1,292.20	3.1113297	9,230.0	3.9652017	4	00	15	8	00	30	16	01	00
4.0	25	1,476.80	3.1693217	9,230.0	3.9652017	4	34	26	9	08	52	18	17	44
4.5	25	1,661.40	3.2204742	9,230.0	3.9652017	5	08	34	10	17	08	20	34	16
4.0	30	1,476.80	3.1693217	11,076.0	4.0443829	3	48	51	7	37	41	15	15	23
4.5	30	1,661.40	3.2204742	11,076.0	4.0443829	4	17	21	8	34	42	17	09	24
5.0	30	1,846.00	3.2662317	11,076.0	4.0443829	4	45	49	9	31	38	19	03	16
4.5	35	1,661.40	3.2204742	12,922.0	4.1113297	3	40	42	7	21	23	14	42	47
5.0	35	1,846.00	3.2662317	12,922.0	4.1113297	4	05	08	8	10	16	16	20	33
5.5	35	2,030.60	3.3076244	12,922.0	4.1113297	4	29	33	8	59	07	17	58	13

Table B

s Sound seconds	r Sound seconds	log R	R Yards	log sin β	log cos β	log sin 2 β	log cos 2 β
3.5	25	3.9662631	9,252.6	9.1440045	9.9957439	9.4407784	9.9828054
4.0	25	3.9665870	9,259.5	9.2013462	9.9944410	9.4968173	9.9774720
4.5	25	3.9669535	9,267.3	9.2517700	9.9929643	9.5457642	9.9713858
4.0	30	4.0453459	11,100.6	9.1230075	9.9961397	9.4201848	9.9844184
4.5	30	4.0456010	11,107.1	9.1736565	9.9951141	9.4698008	9.9802315
5.0	30	4.0458857	11,114.4	9.2188406	9.9939681	9.5138387	9.9755277
4.5	35	4.1122252	12,948.7	9.1073482	9.9964105	9.4047966	9.9855207
5.0	35	4.1124348	12,954.9	9.1526850	9.9955685	9.4492910	9.9820889
5.5	35	4.1126661	12,961.8	9.1936272	9.9946376	9.4892884	9.9782795

Table C

s Sound seconds	r Sound seconds	a Yards	b Yards	c Yards	d Yards	e Yards	L Yards	Log L
3.5	25	180.03	1,292.20	1,279.60	1,242.03	356.54	6,335.46	3.8017781
4.0	25	234.78	1,476.80	1,458.02	1,402.15	463.60	7,197.14	3.8571600
4.5	25	296.65	1,661.40	1,634.70	1,555.47	583.76	8,041.74	3.9053500
4.0	30	196.03	1,476.80	1,463.73	1,424.76	388.60	7,253.78	3.8605644
4.5	30	247.82	1,661.40	1,642.82	1,587.47	490.09	8,121.98	3.9096620
5.0	30	305.54	1,846.00	1,820.54	1,744.85	602.66	8,976.78	3.9531206
4.5	35	212.73	1,661.40	1,647.73	1,606.92	421.96	8,170.70	3.9122221
5.0	35	262.37	1,846.00	1,827.26	1,771.42	519.42	9,043.36	3.9563297
5.5	35	317.14	2,030.60	2,005.68	1,931.54	626.49	9,905.04	3.9958562

Section XII. LENGTHS OF SUB-BASES

169. LENGTHS OF SUB-BASES.

Sound seconds	Length of sub-base		
	Yards	Meters	Miles
STANDARD SUB-BASES			
2	738.40	675.19	0.4195
3	1,107.60	1,012.79	0.6293
4	1,476.80	1,350.39	0.8391
5	1,846.00	1,687.99	1.0489
SPECIAL SUB-BASES FOR MECHANICAL PLOTTING BOARD			
3½	1,292.20	1,181.59	0.7342
4½	1,661.40	1,519.19	0.9440
5½	2,030.60	1,856.78	1.1538

Section XIII. TIME SCALE VALUES

170. TWO-SECOND SUB-BASE.

t Seconds	Sin θ	θ Degrees	θ Mils	Tan θ
0.050	0.02500	1° 26′	25.5	0.02501
0.100	0.05000	2° 52′	51.0	0.05006
0.150	0.07500	4° 18′	76.5	0.07521
0.200	0.10000	5° 44′	102.0	0.10050
0.250	0.12500	7° 11′	127.7	0.12599
0.300	0.15000	8° 38′	153.4	0.15172
0.350	0.17500	10° 05′	179.2	0.17774
0.400	0.20000	11° 32′	205.1	0.20412
0.450	0.22500	13° 00′	231.2	0.23092
0.500	0.25000	14° 29′	257.4	0.25820
0.550	0.27500	15° 58′	283.8	0.28603
0.600	0.30000	17° 27′	310.4	0.31449
0.650	0.32500	18° 58′	337.2	0.34366
0.700	0.35000	20° 29′	364.2	0.37363
0.750	0.37500	22° 01′	391.5	0.40452
0.800	0.40000	23° 35′	419.2	0.43644
0.850	0.42500	25° 09′	447.1	0.46951
0.900	0.45000	26° 45′	475.4	0.50390
0.950	0.47500	28° 22′	504.2	0.53978
1.000	0.50000	30° 00′	533.3	0.57735
1.050	0.52500	31° 40′	563.0	0.61685
1.100	0.55000	33° 22′	593.2	0.65855
1.150	0.57500	35° 06′	624.0	0.70280
1.200	0.60000	36° 52′	655.5	0.75000
1.250	0.62500	38° 41′	687.7	0.80064
1.300	0.65000	40° 32′	720.7	0.85534
1.350	0.67500	42° 27′	754.7	0.91486
1.400	0.70000	44° 26′	789.8	0.98020
1.450	0.72500	46° 28′	826.1	1.05263
1.500	0.75000	48° 35′	863.8	1.13389
1.550	0.77500	50° 48′	903.2	1.22634
1.600	0.80000	53° 08′	944.5	1.33333
1.650	0.82500	55° 35′	988.2	1.45983
1.700	0.85000	58° 13′	1,034.9	1.61357
1.750	0.87500	61° 03′	1,085.2	1.80739
1.800	0.90000	64° 09′	1,140.6	2.06474
1.850	0.92500	67° 40′	1,203.0	2.43442
1.900	0.95000	71° 48′	1,276.5	3.04243
1.950	0.97500	77° 10′	1,371.8	4.38784
2.000	1.00000	90° 00′	1,600.0	Infinity

171. THREE-SECOND SUB-BASE.

t Seconds	Sin θ	θ Degrees	θ Mils	Tan θ
0.100	0.03333	1° 55′	34.0	0.03335
0.200	0.06667	3° 49′	68.0	0.06682
0.300	0.10000	5° 44′	102.0	0.10050
0.400	0.13333	7° 40′	136.2	0.13453
0.500	0.16667	9° 36′	170.6	0.16903
0.600	0.20000	11° 32′	205.1	0.20412
0.700	0.23333	13° 30′	239.9	0.23996
0.800	0.26667	15° 28′	275.0	0.27669
0.900	0.30000	17° 27′	310.4	0.31449
1.000	0.33333	19° 28′	346.2	0.35355
1.100	0.36667	21° 31′	382.4	0.39412
1.200	0.40000	23° 35′	419.2	0.43644
1.300	0.43333	25° 41′	456.5	0.48082
1.400	0.46667	27° 49′	494.5	0.52764
1.500	0.50000	30° 00′	533.3	0.57735
1.600	0.53333	32° 14′	573.0	0.63049
1.700	0.56667	34° 31′	613.7	0.68775
1.800	0.60000	36° 52′	655.5	0.75000
1.900	0.63333	39° 18′	698.6	0.81839
2.000	0.66667	41° 49′	743.3	0.89443
2.100	0.70000	44° 26′	789.8	0.98020
2.200	0.73333	47° 10′	838.5	1.07864
2.300	0.76667	50° 03′	889.9	1.19410
2.400	0.80000	53° 08′	944.5	1.33333
2.500	9.83333	56° 27′	1,003.4	1.50756
2.600	0.86667	60° 04′	1,068.0	1.73720
2.700	0.90000	64° 09′	1,140.6	2.06474
2.800	0.93333	68° 58′	1,226.0	2.59973
2.900	0.96667	75° 10′	1,336.3	3.77548
3.000	1.00000	90° 00′	1,600.0	Infinity

172. THREE AND ONE-HALF-SECOND SUB-BASE.

t Seconds	Sin θ	θ Degrees	θ Mils	Tan θ
0.10	0.0286	1° 38′	29	0.0285
0.20	0.0571	3° 16′	58	0.0571
0.30	0.0858	4° 55′	87	0.0860
0.40	0.1143	6° 34′	117	0.1151
0.50	0.1429	8° 13′	146	0.1444
0.60	0.1714	9° 52′	175	0.1739
0.70	0.2000	11° 32′	205	0.2041
0.80	0.2286	13° 13′	235	0.2349
0.90	0.2571	14° 54′	265	0.2661
1.00	0.2857	16° 36′	295	0.2981
1.10	0.3143	18° 19′	326	0.3310
1.20	0.3429	20° 03′	357	0.3650
1.30	0.3714	21° 48′	388	0.4000
1.40	0.4000	23° 35′	419	0.4365
1.50	0.4286	25° 23′	451	0.4745
1.60	0.4571	27° 12′	484	0.5139
1.70	0.4857	29° 03′	517	0.5555
1.80	0.5142	30° 57′	550	0.5997
1.90	0.5428	32° 52′	584	0.6461
2.00	0.5714	34° 51′	620	0.6963
2.10	0.6000	36° 52′	655	0.7499
2.20	0.6286	38° 57′	693	0.8083
2.30	0.6571	41° 05′	730	0.8718
2.40	0.6857	43° 18′	770	0.9424
2.50	0.7142	45° 34′	810	1.0200
2.60	0.7428	47° 58′	853	1.1093
2.70	0.7714	50° 29′	898	1.2124
2.80	0.8000	53° 08′	945	1.3335

173. FOUR-SECOND SUB-BASE.

t Seconds	Sin θ	θ Degrees	θ Mils	Tan θ
0.100	0.02500	1° 26′	25.5	0.02501
0.200	0.05000	2° 52′	51.0	0.05006
0.300	0.07500	4° 18′	76.5	0.07521
0.400	0.10000	5° 44′	102.0	0.10050
0.500	0.12500	7° 11′	127.7	0.12599
0.600	0.15000	8° 38′	153.4	0.15172
0.700	0.17500	10° 05′	179.2	0.17774
0.800	0.20000	11° 32′	205.1	0.20412
0.900	0.22500	13° 00′	231.2	0.23092
1.000	0.25000	14° 29′	257.4	0.25820
1.100	0.27500	15° 58′	283.8	0.28603
1.200	0.30000	17° 27′	310.4	0.31449
1.300	0.32500	18° 58′	337.2	0.34366
1.400	0.35000	20° 29′	364.2	0.37363
1.500	0.37500	22° 01′	391.5	0.40452
1.600	0.40000	23° 35′	419.2	0.43644
1.700	0.42500	25° 09′	447.1	0.46951
1.800	0.45000	26° 45′	475.4	0.50390
1.900	0.47500	28° 22′	504.2	0.53978
2.000	0.50000	30° 00′	533.3	0.57735
2.100	0.52500	31° 40′	563.0	0.61685
2.200	0.55000	33° 22′	593.2	0.65855
2.300	0.57500	35° 06′	624.0	0.70280
2.400	0.60000	36° 52′	655.5	0.75000
2.500	0.62500	38° 41′	687.7	0.80064
2.600	0.65000	40° 32′	720.7	0.85534
2.700	0.67500	42° 27′	754.7	0.91486
2.800	0.70000	44° 26′	789.8	0.98020
2.900	0.72500	46° 28′	826.1	1.05263
3.000	0.75000	48° 35′	863.8	1.13389
3.100	0.77500	50° 48′	903.2	1.22634
3.200	0.80000	53° 08′	944.5	1.33333
3.300	0.82500	55° 35′	988.2	1.45983
3.400	0.85000	58° 13′	1,034.9	1.61357
3.500	0.87500	61° 03′	1,085.2	1.80739
3.600	0.90000	64° 09′	1,140.6	2.06474
3.700	0.92500	67° 40′	1,203.0	2.43442
3.800	0.95000	71° 48′	1,276.5	3.04243
3.900	0.97500	77° 10′	1,371.8	4.38785
4.000	1.00000	90° 00′	1,600.0	Infinity

174. FOUR AND ONE-HALF-SECOND SUB-BASE.

t Seconds	Sin θ	θ Degrees	θ Mils	Tan θ
0.100	0.02222	1° 16′	22.6	0.02223
0.200	0.04444	2° 33′	45.3	0.04449
0.300	0.06667	3° 49′	68.0	0.06682
0.400	0.08889	5° 06′	90.7	0.08924
0.500	0.11111	6° 23′	113.4	0.11180
0.600	0.13333	7° 40′	136.2	0.13453
0.700	0.15556	8° 57′	159.1	0.15747
0.800	0.17778	10° 14′	182.1	0.18066
0.900	0.20000	11° 32′	205.1	0.20412
1.000	0.22222	12° 50′	228.3	0.22792
1.100	0.24444	14° 09′	251.5	0.25209
1.200	0.26667	15° 28′	275.0	0.27669
1.300	0.28889	16° 47′	298.5	0.30175
1.400	0.31111	18° 08′	322.2	0.32736
1.500	0.33333	19° 28′	346.2	0.35355
1.600	0.35556	20° 50′	370.3	0.38041
1.700	0.37778	22° 12′	394.6	0.40801
1.800	0.40000	23° 35′	419.2	0.43644
1.900	0.42222	24° 58′	444.0	0.46578
2.000	0.44444	26° 23′	469.1	0.49614
2.100	0.46667	27° 49′	494.5	0.52764
2.200	0.48889	29° 16′	520.3	0.56043
2.300	0.51111	30° 44′	546.5	0.59465
2.400	0.53333	32° 14′	573.0	0.63049
2.500	0.55556	33° 45′	600.0	0.66815
2.600	0.57778	35° 18′	627.5	0.70789
2.700	0.60000	36° 52′	655.5	0.75000
2.800	0.62222	38° 29′	684.1	0.79483
2.900	0.64444	40° 07′	713.3	0.84280
3.000	0.66667	41° 49′	743.3	0.89443
3.100	0.68889	43° 33′	774.1	0.95037
3.200	0.71111	45° 20′	805.8	1.01142
3.300	0.73333	47° 10′	838.5	1.07864
3.400	0.75556	49° 04′	872.4	1.15337
3.500	0.77778	51° 03′	907.7	1.23744

t Seconds	Sin θ	θ Degrees	θ Mils	Tan θ
3.600	0.80000	53° 08′	944.5	1.33333
3.700	0.82222	55° 18′	983.3	1.44461
3.800	0.84444	57° 37′	1,024.2	1.57651
3.900	0.86667	60° 04′	1,068.0	1.73720
4.000	0.88889	62° 44′	1,115.3	1.94029
4.100	0.91111	65° 40′	1,167.3	2,21057
4.200	0.93333	68° 58′	1,226.0	2.59973
4.300	0.95556	72° 51′	1,295.2	3.24125
4.400	0.97778	77° 54′	1,384.9	4.66399
4.500	1.00000	90° 00′	1,600.0	Infinity

175. FIVE-SECOND SUB-BASE.

t Seconds	Sin θ	θ Degrees	θ Mils	Tan θ
0.100	0.02000	1° 09′	20.4	0.02000
0.200	0.04000	2° 18′	40.8	0.04003
0.300	0.06000	3° 26′	61.2	0.06011
0.400	0.08000	4° 35′	81.6	0.08026
0.500	0.10000	5° 44′	102.0	0.10050
0.600	0.12000	6° 54′	122.5	0.12087
0.700	0.14000	8° 03′	143.1	0.14139
0.800	0.16000	9° 12′	163.7	0.16209
0.900	0.18000	10° 22′	184.4	0.18299
1.000	0.20000	11° 32′	205.1	0.20412
1.100	0.22000	12° 43′	225.9	0.22553
1.200	0.24000	13° 53′	246.9	0.24723
1.300	0.26000	15° 04′	267.9	0.26926
1.400	0.28000	16° 16′	289.1	0.29167
1.500	0.30000	17° 27′	310.4	0.31449
1.600	0.32000	18° 40′	331.8	0.33776
1.700	0.34000	19° 53′	353.4	0.36154
1.800	0.36000	21° 06′	375.1	0.38587
1.900	0.38000	22° 20′	397.0	0.41082
2.000	0.40000	23° 35′	419.2	0.43644
2.100	0.42000	24° 50′	441.5	0.46280
2,200	0.44000	26° 06′	464.1	0.48998
2.300	0.46000	27° 23′	486.9	0.51807
2.400	0.48000	28° 41′	510.0	0.54715
2.500	0.50000	30° 00′	533.3	0.57735

t Seconds	Sin θ	θ Degrees	θ Mils	Tan θ
2.600	0.52000	31° 20′	557.0	0.60878
2.700	0.54000	32° 41′	581.0	0.64159
2.800	0.56000	34° 03′	605.4	0.67593
2.900	0.58000	35° 27′	630.2	0.71199
3.000	0.60000	36° 52′	655.5	0.75000
3.100	0.62000	38° 19′	681.2	0.79021
3.200	0.64000	39° 48′	707.4	0.83293
3.300	0.66000	41° 18′	734.2	0.87852
3.400	0.68000	42° 51′	761.7	0.92743
3.500	0.70000	44° 26′	789.8	0.98020
3.600	0.72000	46° 03′	818.7	1.03750
3.700	0.74000	47° 44′	848.6	1.10020
3.800	0.76000	49° 28′	879.4	1.16937
3.900	0.78000	51° 16′	911.3	1.24645
4.000	0.80000	53° 08′	944.5	1.33333
4.100	0.82000	55° 05′	979.3	1.43266
4.200	0.84000	57° 08′	1,015.8	1.54814
4.300	0.86000	59° 19′	1,054.5	1.68530
4.400	0.88000	61° 39′	1,095.9	1.85273
4.500	0.90000	64° 09′	1,140.6	2.06474
4.600	0.92000	66° 56′	1,189.8	2.34743
4.700	0.94000	70° 03′	1,245.4	2.75519
4.800	0.96000	73° 44′	1,310.9	3.42857
4.900	0.98000	78° 31′	1,395.9	4.92469
5.000	1.00000	90° 00′	1,600.0	Infinity

176. FIVE AND ONE-HALF-SECOND SUB-BASE.

t Seconds	Sin θ	θ Degrees	θ Mils	Tan θ
0.100	0.01818	1° 03′	18.5	0.01818
0.200	0.03636	2° 05′	37.0	0.03639
0.300	0.05455	3° 08′	55.6	0.05463
0.400	0.07273	4° 10′	74.1	0.07292
0.500	0.09091	5° 13′	92.7	0.09129
0.600	0.10909	6° 16′	111.3	0.10975
0.700	0.12727	7° 19′	130.0	0.12832
0.800	0.14545	8° 22′	148.7	0.14702
0.900	0.16364	9° 25′	167.4	0.16587
1.000	0.18182	10° 29′	186.2	0.18490
1.100	0.20000	11° 32′	205.1	0.20412
1.200	0.21818	12° 36′	224.0	0.22357
1.300	0.23636	13° 40′	243.1	0.24326
1.400	0.25455	14° 45′	262.2	0.26322
1.500	0.27273	15° 50′	281.4	0.28347
1.600	0.29091	16° 55′	300.7	0.30406
1.700	0.30909	18° 00′	320.1	0.32501
1.800	0.32727	19° 06′	339.6	0.34635
1.900	0.34545	20° 13′	359.3	0.36812
2.000	0.36364	21° 19′	379.1	0.39036
2.100	0.38182	22° 27′	399.0	0.41312
2.200	0.40000	23° 35′	419.2	0.43644
2.300	0.41818	24° 43′	439.5	0.46037
2.400	0.43636	25° 52′	459.9	0.48497
2.500	0.45455	27° 02′	480.6	0.51031
2.600	0.47273	28° 13′	501.5	0.53645
2.700	0.49091	29° 24′	522.7	0.56348
2.800	0.50909	30° 36′	544.1	0.59148
2.900	0.52727	31° 49′	565.7	0.62054
3.000	0.54545	33° 03′	587.7	0.65079
3.100	0.56364	34° 18′	609.9	0.68235
3.200	0.58182	35° 35′	632.5	0.71536
3.300	0.60000	36° 52′	655.5	0.75000
3.400	0.61818	38° 11′	678.8	0.78646
3.500	0.63636	39° 31′	702.6	0.82496
3.600	0.65455	40° 53′	726.8	0.86577
3.700	0.67273	42° 17′	751.6	0.90923
3.800	0.69091	43° 42′	776.9	0.95569
3.900	0.70909	45° 10′	802.9	1.00564
4.000	0.72727	46° 39′	829.5	1.05963

t Seconds	Sin θ	θ Degrees	θ Mils	Tan θ
4.100	0.74545	48° 12′	856.9	1.11837
4.200	0.76364	49° 47′	885.1	1.18275
4.300	0.78182	51° 26′	914.3	1.25391
4.400	0.80000	53° 08′	944.5	1.33333
4.500	0.81818	54° 54′	976.1	1.42302
4.600	0.83636	56° 45′	1,009.0	1.52572
4.700	0.85455	58° 43′	1,043.7	1.64533
4.800	0.87273	60° 47′	1,080.5	1.78761
4.900	0.89091	62° 59′	1,119.8	1.96157
5.000	0.90909	65° 23′	1,162.3	2.18218
5.100	0.92727	68° 01′	1,209.1	2.47678
5.200	0.94545	70° 59′	1,262.0	2.90236
5.300	0.96364	74° 30′	1,324.5	3.60619
5.400	0.98182	79° 03′	1,405.5	5.17226
5.500	1.00000	90° 00′	1,600.0	Infinity

Section XIV. SOUND RANGING CORRECTION CHARTS

177. SOUND RANGING CORRECTION CHARTS. See figures 144 to 158, inclusive.

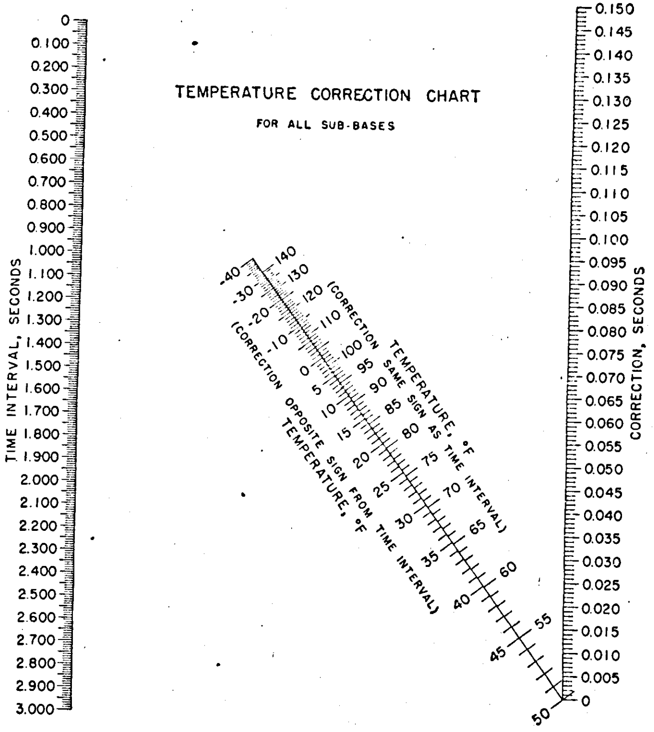


Figure 144. Temperature correction chart for all sub-bases.

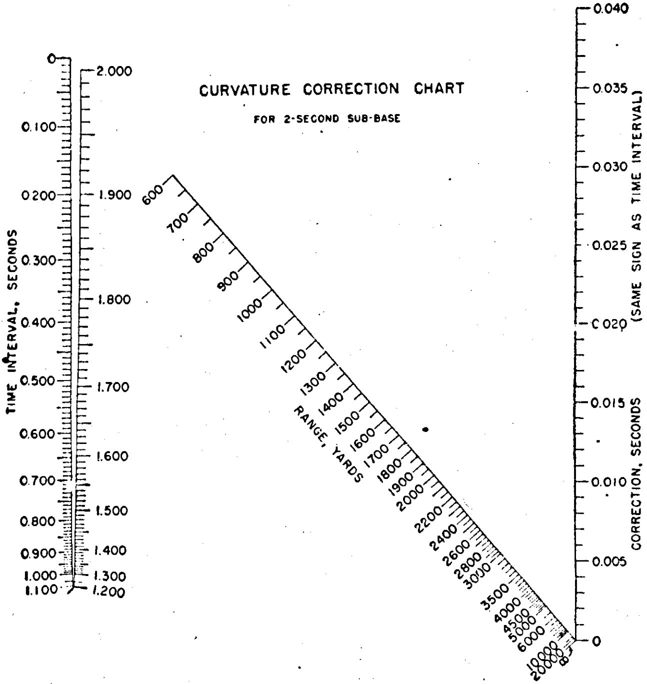


Figure 145. Curvature correction chart, 2-second sub-base.

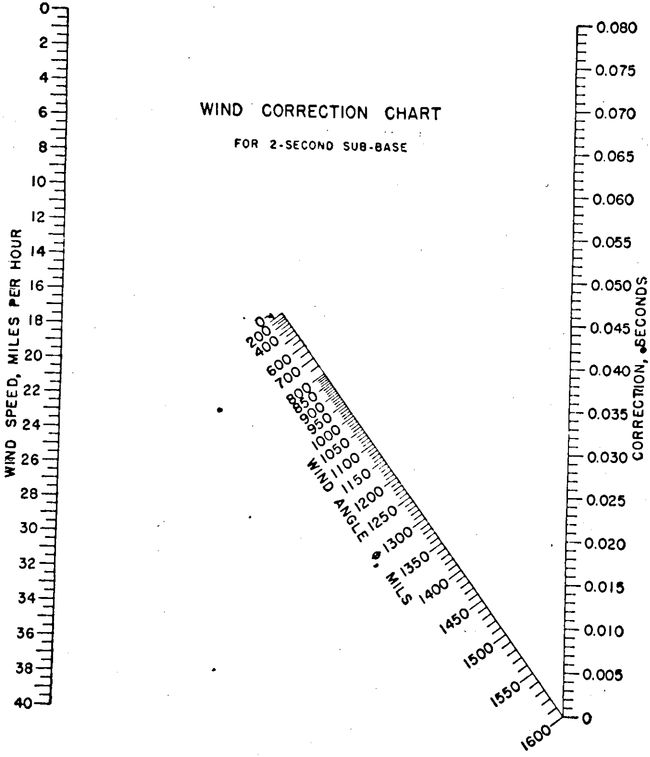


Figure 146. Wind correction chart, 2-second sub-base.

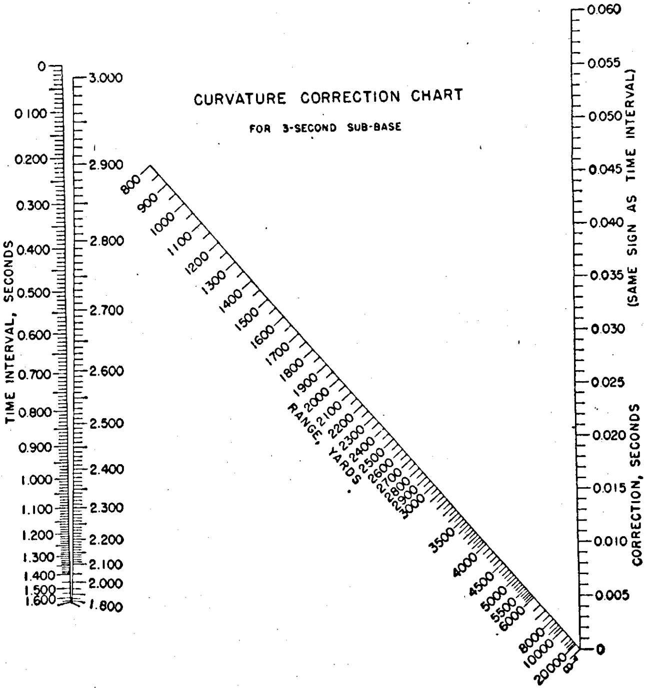


Figure 147. Curvature correction chart, 3-second sub-base.

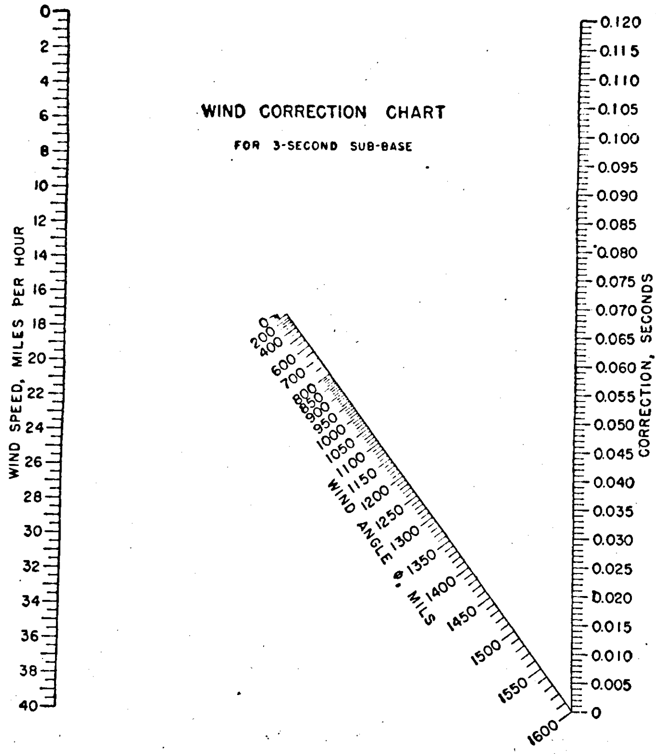


Figure 148. Wind correction chart, 3-second sub-base.

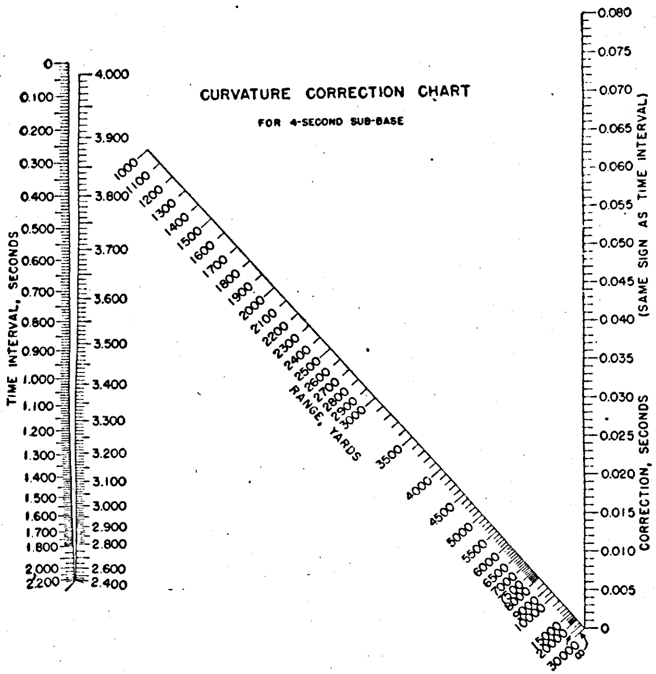


Figure 149. Curvature correction chart, 4-second sub-base.

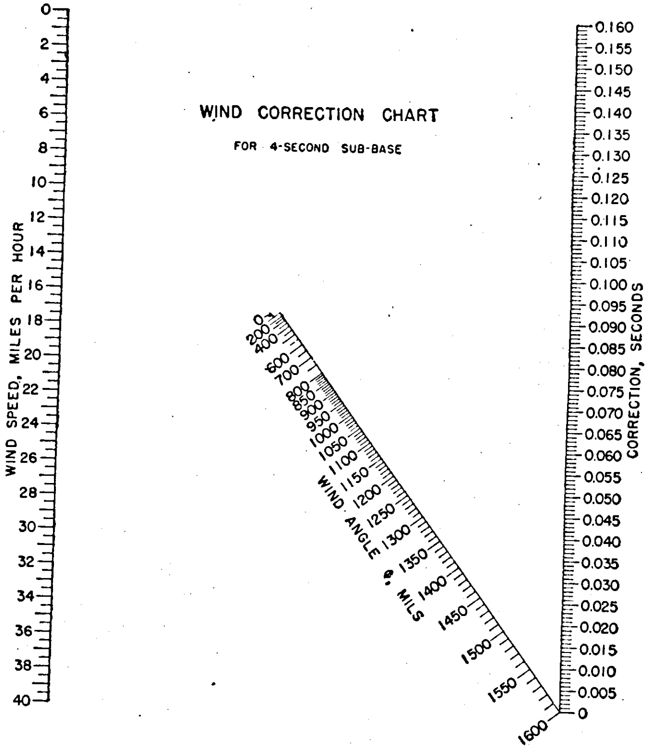


Figure 150. Wind correction chart, 4-second sub-base.

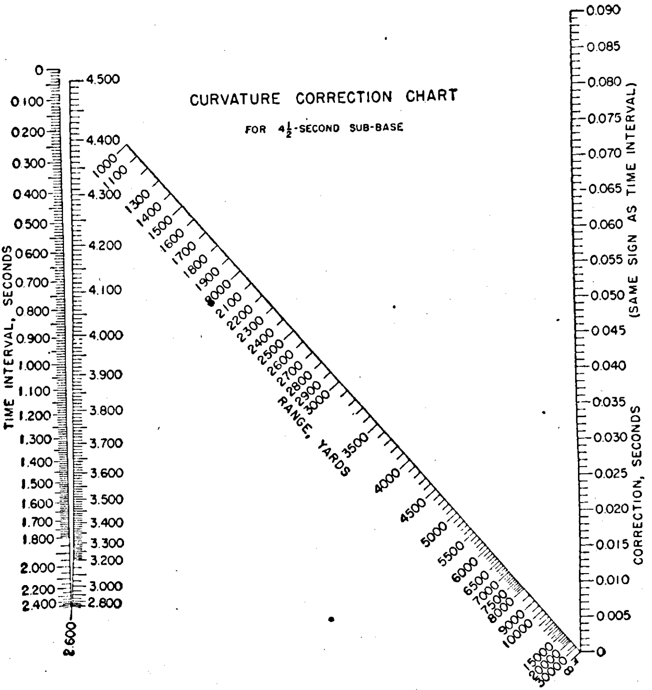


Figure 151. Curvature correction chart, 4½-second sub-base.

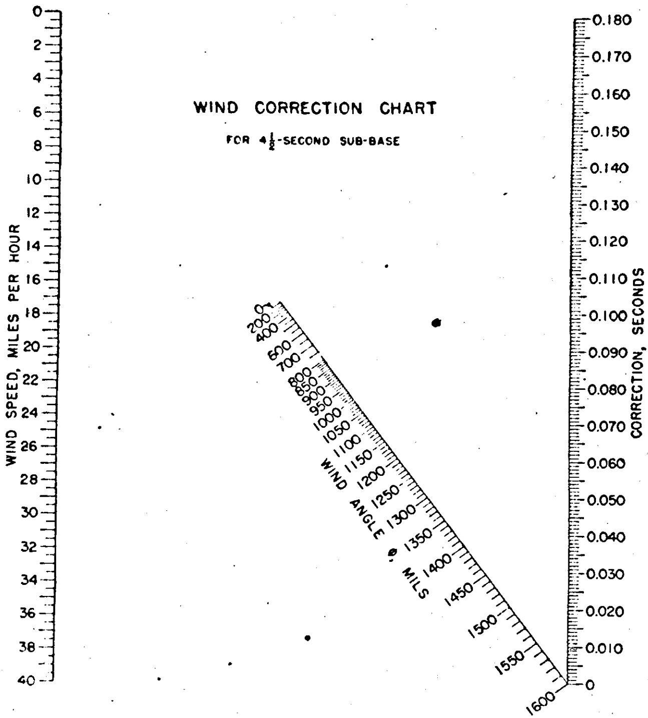


Figure 152. Wind correction chart, 4½-second sub-base.

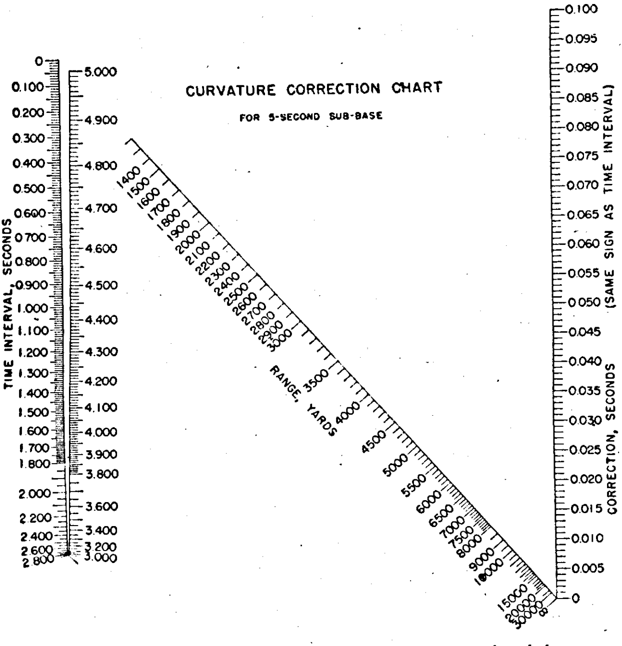


Figure 153. Curvature correction chart, 5-second sub-base

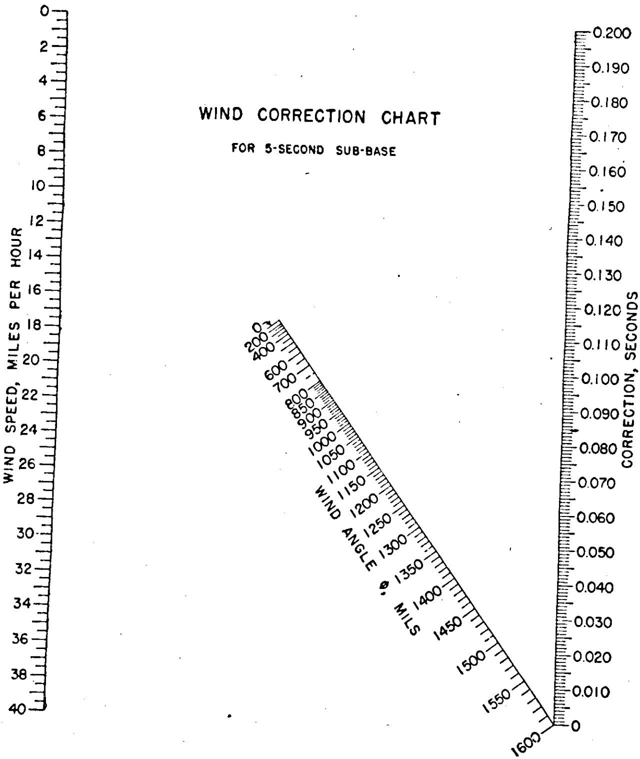


Figure 154. Wind correction chart, 5-second sub-base.

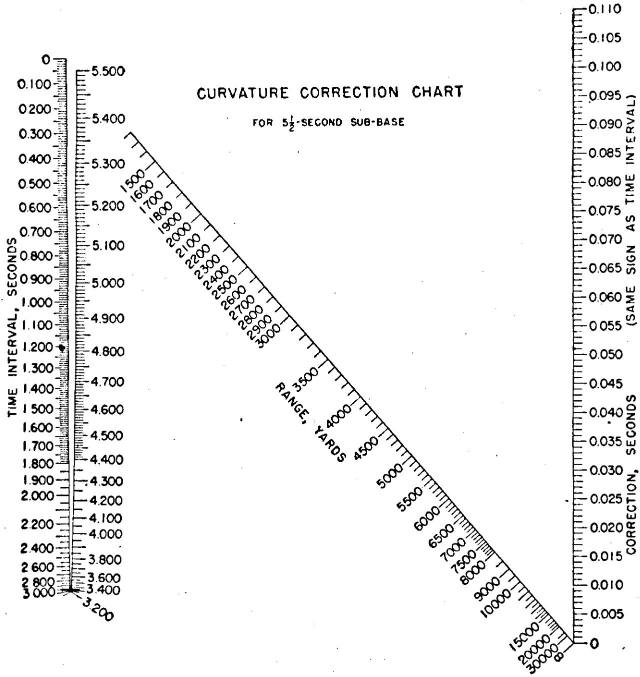


Figure 155. Curvature correction chart, 5½-second sub-base.

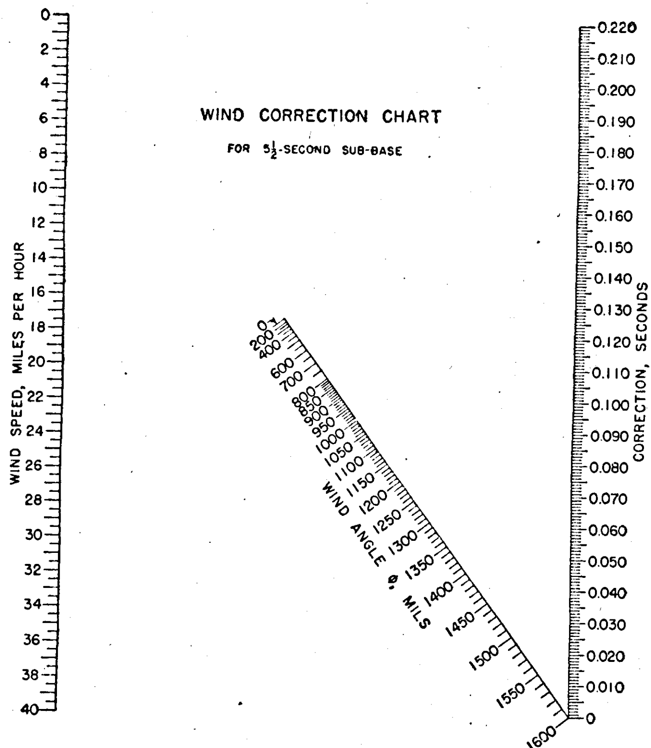


Figure 156. Wind correction chart, 5½-second sub-base.

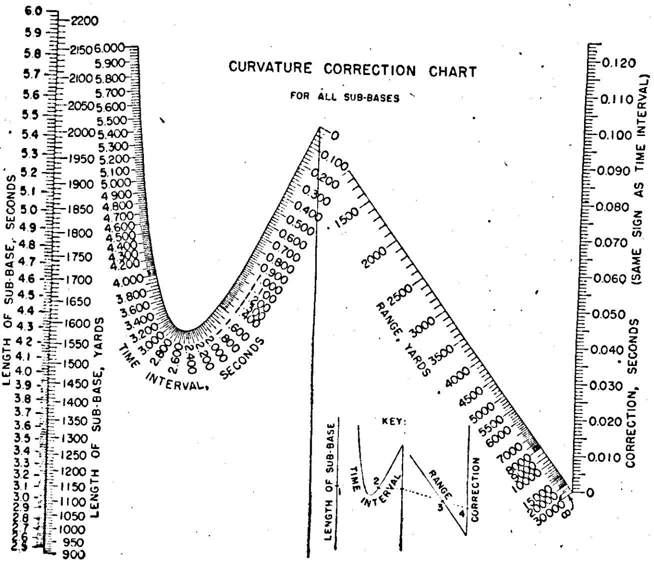


Figure 157. Curvature correction chart, any length sub-base.

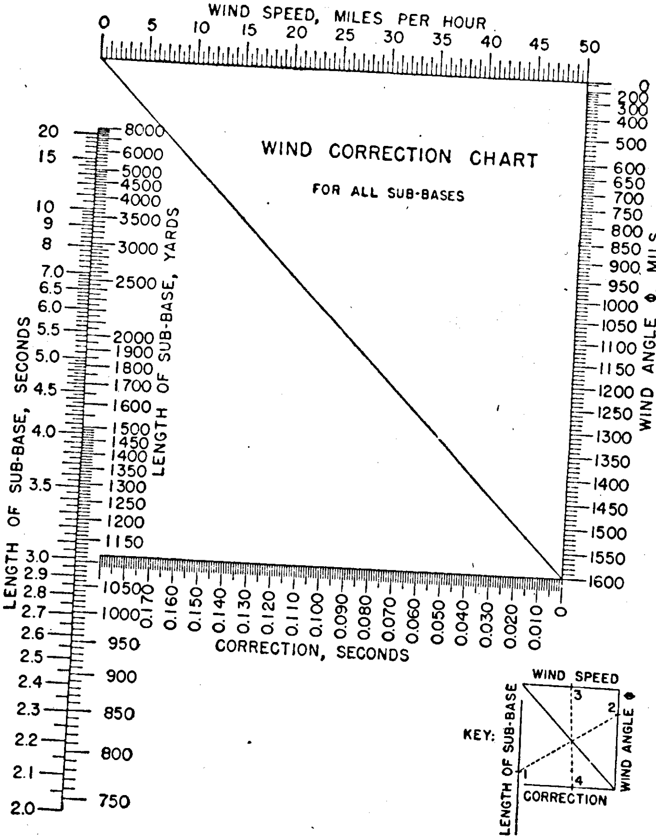


Figure 158. Wind correction chart, any length sub-base.

178. VELOCITY OF SOUND IN AIR.

$$V_x = 369.20\sqrt{\frac{X+458.5}{508.5}} \text{ yards per second}$$

Where X = temperature in °F.

Effects of both temperature and humidity are taken into account if table is entered with virtual temperature.

Temperature (°F)	Velocity (yds/sec)	Log of velocity	Temperature (°F)	Velocity (yds/sec)	Log of velocity
−40	334.94	2.52496	−10	346.73	2.54000
−39	335.34	2.52548	− 9	347.12	2.54048
−38	335.74	2.52600	− 8	347.51	2.54096
−37	336.14	2.52652	− 7	347.89	2.54145
−36	336.53	2.52703	− 6	348.28	2.54193
−35	336.93	2.52754	− 5	348.66	2.54240
−34	337.33	2.52806	− 4	349.05	2.54288
−33	337.73	2.52857	− 3	349.43	2.54336
−32	338.12	2.52908	− 2	349.81	2.54384
−31	338.52	2.52958	− 1	350.20	2.54431
−30	338.92	2.53009	0	350.58	2.54479
−29	339.31	2.53060	1	350.96	2.54526
−28	339.71	2.53110	2	351.34	2.54573
−27	340.10	2.53161	3	351.72	2.54620
−26	340.49	2.53211	4	352.10	2.54667
−25	340,89	2.53261	5	352.49	2.54714
−24	341.28	2.53311	6	352.87	2.54761
−23	341.67	2.53361	7	353.24	2.54808
−22	342.06	2.53411	8	353.62	2.54854
−21	342.46	2.53461	9	354.00	2.54901
−20	342.85	2.53510	10	354.38	2.54947
−19	343.24	2.53560	11	354.76	2.54993
−18	343.63	2.53609	12	355.14	2.55040
−17	344.02	2.53658	13	355.51	2.55086
−16	344.41	2.53707	14	355.89	2.55132
−15	344.80	2.53756	15	356.27	2.55178
−14	345.19	2.53805	16	356.64	2.55223
−13	345.57	2.53854	17	357.02	2.55269
−12	345.96	2.53903	18	357.39	2.55315
−11	346.35	2.53951	19	357.77	2.55360
−10	346.73	2.54000	20	358.14	2.55406

Temperature (°F)	Velocity (yds/sec)	Log of velocity	Temperature (°F)	Velocity (yds/sec)	Log of velocity
20	358.14	2.55406	60	372.81	2.57149
21	358.52	2.55451	61	373.17	2.57191
22	358.89	2.55496	62	373.53	2.57233
23	359.26	2.55541	63	373.89	2.57274
24	359.64	2.55586	64	374.25	2.57316
25	360.01	2.55631	65	374.61	2.57357
26	360.38	2.55676	66	374.96	2.57399
27	360.75	2.55721	67	375.32	2.57440
28	361.13	2.55766	68	375.68	2.57482
29	361.50	2.55810	69	376.03	2.57523
30	361.87	2.55855	70	376.38	2.57563
31	362.24	2.55899	71	376.75	2.57605
32	362.61	2.55944	72	377.10	2.57646
33	362.98	2.55988	73	377.46	2.57687
34	363.35	2.56032	74	377.81	2.57728
35	363.71	2.56076	75	378.17	2.57768
36	364.08	2.56120	76	378.52	2.57809
37	364.45	2.56164	77	378.88	2.57850
38	364.82	2.56208	78	379.23	2.57890
39	365.18	2.56251	79	379.58	2.57931
40	365.55	2.56295	80	379.93	2.57971
41	365.92	2.56338	81	380.29	2.58011
42	366.28	2.56382	82	380.64	2.58051
43	366.65	2.56425	83	380.99	2.58092
44	367.02	2.56468	84	381.34	2.58132
45	367.38	2.56512	85	381.69	2.58172
46	367.74	2.56555	86	382.05	2.58212
47	368.10	2.56598	87	382.40	2.58251
48	368.47	2.56641	88	382.75	2.58291
49	368.84	2.56683	89	383.10	2.58331
50	369.20	2.56726	90	383.45	2.58170
51	369.56	2.56769	91	383.80	2.58410
52	369.93	2.56811	92	384.14	2.58449
53	370.29	2.56854	93	384.49	2.58489
54	370.65	2.56896	94	384.84	2.58528
55	371.01	2.56939	95	385.19	2.58568
56	371.37	2.56981	96	385.54	2.58607
57	371.73	2.57023	97	385.89	2.58646
58	372.09	2.57065	98	386.23	2.58685
59	372.45	2.57107	99	386.58	2.58724
60	372.81	2.57149	100	386.93	2.58763

Temperature (°F)	Velocity (yds/sec)	Log of velocity	Temperature (°F)	Velocity (yds/sec)	Log of velocity
100	386.93	2.58763	120	393.79	2.59527
101	387.27	2.58802	121	394.13	2.59564
102	387.62	2.58840	122	394.47	2.59602
103	387.96	2.58879	123	394.81	2.59639
104	388.31	2.58918	124	395.15	2.59676
105	388.65	2.58956	125	395.49	2.59714
106	389.00	2.58995	126	295.83	2.59751
107	389.34	2.59033	127	396.17	2.59788
108	389.69	2.59072	128	396.51	2.59825
109	390.03	2.59110	129	396.84	2.59862
110	390.37	2.59148	130	397.18	2.59899
111	390.72	2.59186	131	397.52	2.59936
112	391.06	2.59224	132	397.86	2.59973
113	391.40	2.59262	133	398.19	2.60009
114	391.75	2.59300	134	398.53	2.60046
115	392.09	2.59338	135	398.87	2.60083
116	392.43	2.59376	136	399.20	2.60119
117	392.77	2.59414	137	399.54	2.60156
118	393.11	2.59452	138	399.87	2.60192
119	393.45	2.59489	139	400.21	2.60229
120	393.79	2.59527	140	400.54	2.60265

Note.—The table above, computed using the equation given at the beginning of the paragraph, has been found by experiment to produce slightly better results than the corresponding equation in paragraph 83d(3).

APPENDIX I

SOUND RANGING WITH DODAR

Section I. GENERAL

1. INTRODUCTION. This appendix describes the Dodar sound ranging system, and its operation and employment in field artillery sound ranging. The basic principles of sound ranging are described in chapter 5. The Dodar sound ranging system is placed in an appendix because certain modifications in the application of these principles are made necessary by differences in equipment used. The Dodar system is particularly useful when hasty sound ranging installations are desired, and for accurate ranging on targets, such as light artillery and mortars, at short distances.

2. DESCRIPTION OF EQUIPMENT. a. One Dodar sound ranging system consists of two or more Dodar sound ranging sets. Each set includes an indicator, a battery case, batteries, microphones, and accessories. Acoustic couplers are provided for the modification of microphone T–21–B. The method of modification and the equipment needed are fully described in TM 11–2565. Acoustic couplers are not required for microphone T–23–( ), but its high frequency plug should be used.

b. The indicator is a device which measures on a direct reading meter, calibrated in thousandths of seconds (milliseconds), the time interval between arrivals of sound at each of two microphones; the sense of the deflection of the meter (right or left) depends upon the microphone which first received the sound. The two microphones are connected by

wire circuits to the time interval indicator. The combination serves as an independently operated sound ranging sub-base, by means of which the direction of approach of a sound may be determined. The time interval meter will register time intervals up to + 300 or — 300 milliseconds. A schematic installation at one sub-base is shown in figure 159. An operator, or reader, is required for each indicator whenever the system is in operation.

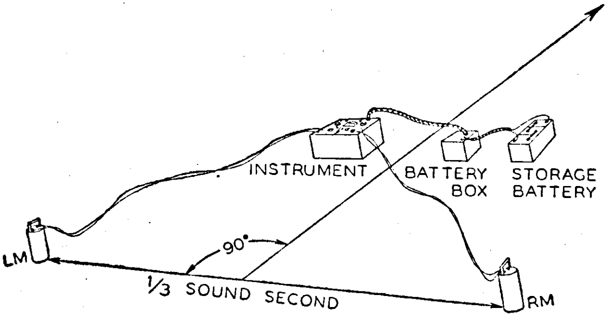


Figure 159. Equipment at one sub-base.

Section II. SELECTION OF POSITION

3. SOUND BASE. a. General. The sound ranging base consists of *at least* three independent sub-bases. Sub-bases are numbered from right to left when facing the front or the direction in which it is desired to sound range. The pair of microphones which constitute a sub-base are designated as the right and left microphones of that sub-base. (See fig. 2.)

b. Lengths of sub-bases. Sub-base lengths are normally ⅓ or ½ sound second in order that time scales and correction charts for standard sub-bases may be conveniently used. With these lengths, under standard conditions, directions of sound approach may be measured within angles of

approximately 60° and 35°, respectively, to either side of the perpendicular bisector of the sub-base or sub-base normal. In general, the shorter sub-base should be used when targets at short ranges or targets distributed over wide areas are being located. If the target area is narrow, and greater accuracy is desired, a 2/3 sound second sub-base may be used, permitting determination of direction within approximately 25° of either side of the sub-base normal.

c. Location of sub-bases. (1) The relative locations of the sub-bases used will normally be determined by terrain, situation, and distance to the target area. Sub-base locations may be selected by inspection from maps or air photographs, but as thorough ground reconnaissance as possible should be made. For best results, the distance between flank sub-bases should be about one-half the distance from the base to the center of the target area (angle of intersection of flank sub-base normals approximately 500 mils), although satisfactory results may be obtained, under favorable conditions, with sub-bases closer together. Each sub-base should be so oriented that its normal, or perpendicular bisector, passes as nearly as possible through the center of the target area. (See fig. 160.)

(2) Since no outpost operator is required for operation of Dodar, the sound base may be installed somewhat closer to the front lines than is possible with standard sound ranging equipment.

d. Location of microphones. The criteria of a good microphone position are not altered by changes in sound recording equipment, except that *both microphones of each Dodar sub-base should be located in similar terrain.* If one microphone is located in woods or brush, its associated microphone should be in woods or brush; if one microphone is in the open, its mate should also be in the open.

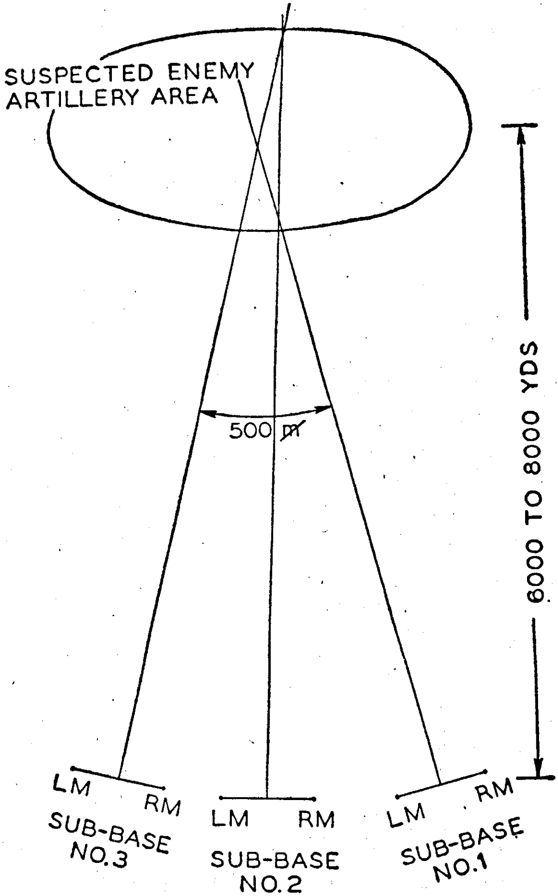


Figure 160. Location of Dodar base with respect to area of suspected location of enemy artillery.

However, one sub-base may be located in one type of terrain while others of the same base are in terrain of a different nature.

e. Location of indicators. (1) Each time interval indicator may be located near its sub-base, or all indicator sets may be placed at the sound ranging central. If the former method of employment is used, the indicator should be 25 to 50 yards ahead of the microphones. Thus the sound will alert the operator and aid him in selecting the desired reading.

(2) If all indicator sets are located at the sound ranging central, more wire must be installed and flexibility of operation is sacrificed, but this method permits centralized control of operations, and requires fewer personnel for maintenance of local security.

4. SOUND RANGING CENTRAL. a. To reduce the amount of wire to be laid, the sound ranging central should be as near the center of the sound base as is consistent with security. It should be selected to provide cover and concealment for personnel and a covered route of approach.

b. The sound ranging central may be located in front of the sub-base farthest forward to enable the sound officer to select personally the sounds to be recorded.

Section III. INSTALLATION

5. SURVEY OF SOUND BASE. a. General. A Dodar sound ranging base will usually be installed by hasty methods of survey, but when survey control is brought forward, the survey of the base may be improved for accurate location of targets at short distances.

b. Internal survey. (1) *Direct taping.* The relative locations of the two microphones which constitute a sub-base, and the azimuth of the line connecting them, may be determined by normal survey methods or by use of a steel tape and declinated compass.

(2) *Calibrated wire method.* (*a*) If the time interval indicator is located at its sub-base, the length of the sub-base may be quickly measured by use of two previously prepared 1/6-second (184.6 feet) or ¼-second (276.9 feet) lengths of field wire (calibrated wire), which may serve also as wire circuits from the microphones to the indicator if sufficient slack wire is provided at each end. Alignment of the two halves of the base may be made by eye. The azimuth of the base may be determined by means of a declinated compass.

(*b*) If all the time interval indicators are located at the sound ranging central, the calibrated wire is still a convenient means of determining sub-base lengths; however, in this case, the calibrated wire will not serve in a microphone circuit.

c. Connecting survey. The location of the various sub-bases with respect to each other and to the supported firing units may be determined initially by inspection from a map or photomap. When survey control is available, survey of the Dodar base may be improved by any convenient method. Since it is usually possible to measure short distances very accurately even when hasty methods are used, sub-base *lengths* established by hasty methods may be sufficiently accurate, and on favorable terrain final determinations of the coordinates and azimuths of the various sub-bases may be conveniently made by triangulation.

6. INSTALLATION OF EQUIPMENT. Wire is installed and microphones emplaced as prescribed for standard sound ranging bases.

7. ORGANIZATION OF SOUND RANGING CENTRAL. If the time interval indicators are centrally located, the sound plotting group should be near at hand to permit

readers and plotters to work together. If each indicator is at its sub-base, either radio or wire communication with the sound plotting central will be necessary. In either case, wire circuits should be connected and tested promptly, and sound plotting equipment prepared for operation without delay. Concealment and protection of equipment should be made as complete as possible in the time available.

8. RECORDING. a. General. The technique of operating and maintaining the time interval indicator is described in TM 11–2565. For convenience, adjustments and calibrations which may be made on the Dodar set in the field are described below.

b. Starting procedure and calibration during operation (fig. 161). (1) *General.* Provision is made to calibrate the indicator for operation without the aid of external equipment. This calibration compensates for changes in voltage of batteries and changes in characteristics of tubes during their useful lives. The meter SELECTOR switch and three calibration switches (CAL–1, CAL–2, and CAL–3) are all the equipment necessary to make this field calibration.

(2) (*a*) Before the battery cable is connected to the indicator, the position of the needle of the time interval meter should be checked and, if necessary, accurately set to zero by means of the meter adjusting screw located on the front of the meter.

(*b*) Operate the OFF-FIL-ON switch and rotate the right-hand and left-hand gain controls to their OFF positions.

(3) When the batteries have been connected to the indicator, the set is put into operation by using the starting procedure below.

(*a*) Turn the OFF-FIL-ON switch to the FIL. position. (This should be done as soon as the indicator and batteries

are connected, while waiting for microphone circuits to be completed.)

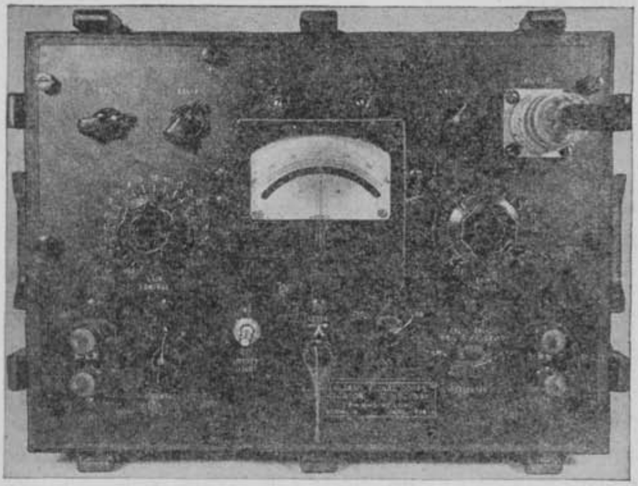


Figure 161. The indicator ID 118/PNS–1.

(*b*) Wait 1 minute after turning the OFF-FIL.-ON switch to the FIL. position, then turn the OFF-FIL.-ON switch to the ON position.

(*c*) As each microphone circuit is connected to the indicator, a polarity test must be made. With the SELECTOR switch on LM or RM, as the case may be, when the microphone leads are attached, the meter needle should deflect to 40 or 50 milliseconds, pause, then rise to about 90 or 100. If the needle deflects in one smooth motion to 40 milliseconds, and remains at that value, the polarity of the microphone is reversed, and the leads should be switched at the indicator.

Note.—The following settings should be carefully and accurately made.

(*d*) Turn the SELECTOR switch to the CAL–1 position. Operate the RESET lever and hold it in the operated posi-

tion while adjusting the control knob CAL–1 to produce a meter reading of —170, as indicated by the arrow on the meter scale.

(*e*) Turn the SELECTOR switch to the CAL–2 position. Operate the RESET lever and hold it in the operated position while adjusting the control knob CAL–2 to produce a meter reading of zero.

(*f*) Turn the SELECTOR switch to the CAL–3 position. Operate the RESET lever and hold it in the operated position while adjusting the control knob CAL–3 to produce a meter reading of zero.

Note.—When operating the set, it is possible to cause a static electric charge to accumulate on the glass of the meter, which results in erratic action of the meter needle. This condition can be eliminated by breathing on the meter glass.

(*g*) Turn the SELECTOR switch to the MEAS position. (In this position the meter needle need not rest on zero, but time intervals will be accurately measured when the set is "triggered.")

(*h*) Turn the frequency control switch to the N position for normal operation. For ranging on higher-pitched sounds, such as mortars, under windy conditions, the switch may be turned to the H position. When the sounds to be recorded are low pitched, performance may be improved by turning the switch to the L position. In this position the set is most sensitive to wind noise.

(*i*) Turn the left-hand gain control clockwise one notch at a time until the circuit "triggers" (the indicator light, L, will be extinguished). If the circuit continues to trigger after each operation of the RESET switch, the presence of extraneous noise, such as might be caused by wind or trucks, is indicated. The gain control should be adjusted to the highest position at which the indicator light is not extinguished by extraneous noise.

(*j*) The procedure described above must be followed for the right-hand gain control and its associated indicator light, R.

(4) The instrument is now adjusted and ready for operation.

Note.—The indicator set should be adjusted by the method described above at least once every 30 minutes during operation.

c. Field calibration of the time interval meter. The accuracy of the time interval meter may be checked in the field, without additional equipment, by a method described in TM 11–2565.

d. Reading and recording time intervals. (1) When calibration has been completed as described above, the set is in stand-by position and is ready for sound ranging. When a sound impulse is received at each microphone, the corresponding indicator lamps are extinguished, and the meter needle deflects. The meter reading is estimated to the nearest millisecond and reported to the sound ranging central. Readings are reported by designating the sub-base, the sense of the reading (plus or minus), and the amount of the reading in milliseconds; for example, NUMBER TWO, PLUS (MINUS), ZERO FOUR THREE. If both indicator lamps are extinguished simultaneously, and the needle does not deflect, the sound has arrived from the direct front, and the reading is ZERO ZERO ZERO. *As soon as the meter has been read, and the reading recorded, the RESET switch must be operated to return the indicator to stand-by position.*

Note.—To insure maximum accuracy, the reader should line up the needle and the image of his eye in the mirror under the meter scale before he reads the meter. Great care should be taken to read the meter accurately to the nearest millisecond.

(2) The recorder will enter the announced reading in the proper column of FAS Form 4 (fig. 162) as *time interval.* Since time intervals, not arrival times, are obtained

from the indicator, the section of Form 4 which is normally used for computing time intervals will be left blank, or used for averaging several time intervals if an average is to be plotted.

SOUND PLOTTING RECORD

Base: Location ELGIN Type 1/3-SEC DODAR Azimuth 1: 100°32′ 2: 114°05′ 3: 128°40′ Date 8 MAR

RECORD ~~Oscillogram~~ No. 2 Time 1050 Temperature 35 °F Wind: Direction 1700 mils Speed 18 mph

Time Readings	+	−	+	−	+	−	+	−	+	−
~~Results to (−)~~		120		007	064					
1 READINGS	⊕	122	⊕	007	⊕065		⊕		⊕	
~~Results to (+)~~		121		006	062					

	1		2		3		4		5	
	+	−	+	−	+	−	+	−	+	−
AVERAGE Time Interval		121		007	064					
Curvature Correction										
Temperature Corr.	002		000			001				
Wind Correction		008		008		007				
Sub-Totals	002	129		015	064	008				
Subtract		002			008					
Corrected Time Interval		127		015	056					
Approximate Range										

Coordinates: X 65.62 Y 01.37 Accuracy 100 yards Caliber 81-mm MORTAR File No. A2D

Area Shelled 65.9 − 02.8 No. of Pieces 1 Time Reported 1053 Conc. No. 16

FAS Form No. 4 FAS, Fort Sill, Okla., (10-4-44—8,000)—30164 367-368-A

Figure 162. FAS Form 4 modified for use with Dodar.

9. PLOTTING. a. General. The basic equation of sound plotting is used for Dodar plotting:

$$\sin \theta = \frac{t}{s}, \tag{1}$$

where θ is the angle between the sub-base normal and the plotted ray; t is the measured time interval, in seconds; and s is the sub-base length, in sound seconds. Sound plotting may be conveniently performed on a grid sheet used as a sound plotting chart, with the center points and reference lines (sub-base normals) for each sub-base plotted on the chart. Since short sub-bases are being used, it will not be necessary to apply an asymptote correction. Consequently, a rough plot need be made only if it is desired to verify that all Dodar installations are ranging on the same sound. In the event that the time interval reported by one reader appears to be inconsistent with the others, the rough plot may be used to determine the approximate time interval which the reader should seek.

b. Weather corrections. (1) *General.* Temperature and wind corrections may be applied by use of the temperature and wind correction charts shown in section XIV, chapter 9, or computed from weather correction formulae given in paragraph 83d. Weather corrections are determined and entered in the proper lines in FAS Form 4.

(2) *Effective wind.* Since Dodar sound ranging bases will usually be used for location of targets at distances less than 6,000 to 8,000 yards, the *average wind up to a height of 240 yards* (first-minute wind) should be used as the effective wind for sound ranging.

(3) *Effective temperature.* The effective temperature for Dodar sound ranging is the same as that for long base sound ranging.

(4) *Use of weather correction charts.* (*a*) *Temperature correction.* Since the temperature correction is independent of the sub-base length, any temperature correction chart may be used. However, the standard temperature correction alignment chart, figure 144, is more convenient to use

if all values on the time interval and correction scales are multiplied by 0.1.

(*b*) *Wind correction.* A wind corrector prepared for a sub-base of length s_b may be used to compute the correction for a sub-base of length s_a if the correction so obtained is *divided* by the ratio $\frac{s_b}{s_a}$. For example, if the corrector is prepared for a 4-second sub-base, and a ½-second sub-base is in use, the value obtained from the corrector is divided by 8.

c. Final plot. Corrected time intervals are computed, the final plot is made, and the polygon of error solved as prescribed for standard sound ranging methods.

d. Relative locations. (1) A Dodar system may be used to obtain relative locations and to conduct sound ranging adjustments, as described for standard sound ranging systems in chapter 5. Standard methods of forcing plots may be used.

(2) The ⅓- and ½-second sub-bases are particularly useful for this purpose, since a simple approximate relation exists between observed time interval difference and the angular difference between directions of approach of two sounds. For a ½-second sub-base, a change of 1 millisecond in meter reading corresponds to a change of 2 mils in direction of sound approach. Thus, if the meter readings obtained for two adjusting rounds were 122 and 127 milliseconds, respectively, the second round fell approximately 10 mils to the right of the first.

(3) If a ⅓-second sub-base is used, the factor by which the time interval difference is multiplied to give the difference between the directions of two sounds must be varied with the meter reading. Between −170 and +170 milli-

seconds, this factor is 3. Between 170 and 250 (or −170 and −250) milliseconds, the factor is 4, while for readings greater in magnitude than 250 milliseconds, a factor of 5 should be used.

10. METHODS OF PLOTTING. a. Plots may be made with standard sound plotting fans if the time intervals are multiplied by the proper factor, but care must be taken to apply weather corrections *before* performing the multiplication, unless only a rough plot is to be made. For example, if it is desired to plot with a 4-second fan a time interval obtained on a ½-second sub-base, the time interval must be *multiplied* by the ratio of 4 to ½, or 8. Since an angle is being plotted, this relation is not affected by the scale at which the plot is made.

b. Range-deflection fan. Locations may be plotted by use of the range-deflection fan, if angles are computed by solving equation (1), paragraph 9, by means of a slide rule. If accurate locations are being made, the temperature correction may be applied automatically by setting off the sub-base length in sound seconds at the existing temperature and humidity rather than under standard conditions. If this method is used, no temperature correction is entered on FAS Form 4.

11. OPERATING PROCEDURE. a. Personnel required. The actual operation of a Dodar sound ranging base requires a minimum of one reader and one recorder for each Dodar set, and three men at the plotting center. These men have the following duties:

Dodar reader. Sets up and operates sub-base. Keeps indicator calibrated, selects sounds to be recorded, and reads and reports time intervals to recorder.

Recorder at sub-base. Assists in setting up sub-base. Records time intervals read at that sub-base and reports

them to plotting center. Alternates with reader each half hour.

Master recorder. Receives time intervals from sub-bases and records on master sheet; determines average time intervals and reports them to the computer.

Computer. Applies wind and temperature corrections to average time intervals and reports them to the draftsman. Receives and records target locations from the draftsman.

Draftsman. Sets up the plotting board, plots corrected time intervals, selects intersection of rays (or center of polygon of error), scales location of targets, and reports locations to the computer.

A sound ranging officer and sound ranging noncommissioned officer should supervise and control each base. Their duties are as follows:

Sound officer. Makes reconnaissance, selects sub-base locations and plotting center location, supervises installation, operation, and maintenance of the Dodar base, reports target locations, and conducts adjustments (registrations) of fire.

Sound noncommissioned officer. Supervises installation, operation, and maintenance of the Dodar base, and, in the absence of sound officer, reports target locations and conducts adjustment (registration) of fire.

Additional personnel should be used, as needed, for survey and installation of the Dodar base, maintenance of wire and equipment, and for relief of crews for continuous operation.

b. Sound ranging location. (1) When sub-bases have reported READY TO RANGE, sound officer may order RANGE IN GENERAL. The first sub-base reader who hears a gun report commands READ. Each sub-base reader receives this command by party-line telephone or over a

common radio net, and records the reading of time interval at his sub-base.

(2) The readings are reported to the plotting center, and an uncorrected plot is made. If the polygon of error is small or the location appears reasonable, the sound officer orders RANGE ON READING REPORTED—RECORD. Any sub-base failing to receive that sound or whose plotted ray is obviously in error is given an approximate reading scaled from the chart. All other sounds are ignored and only those from the desired direction are read and recorded.

(3) The sub-base which first receives the sound from the desired direction continues to alert the other sub-bases by commanding READ. Readings are recorded at each sub-base.

(4) The master recorder commands REPORT. Each sub-base reports in order from right to left. A check mark is placed after each reading on the sub-base record sheet when that reading is reported to the master recorder.

(5) All sub-bases continue to range in the desired direction until given the command CHANGE TARGET.

12. USE OF DODAR AS OUTPOST EQUIPMENT. When a standard sound base is being used and it is desired to range in a specified direction, one Dodar sub-base may be used by the outpost observer as an instrument to assist in selecting those sounds which come from the desired direction. Having been given the time intervals corresponding to the limiting directions of observation, the outpost observer will mark these values on the window of the meter with a china marking pencil, and will operate his outpost set only when the meter needle is deflected to a position between the marks.

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☆ U. S. GOVERNMENT PRINTING OFFICE: 1945—640712